POWER PLANT ENGINEERING

Established Over 34 Years

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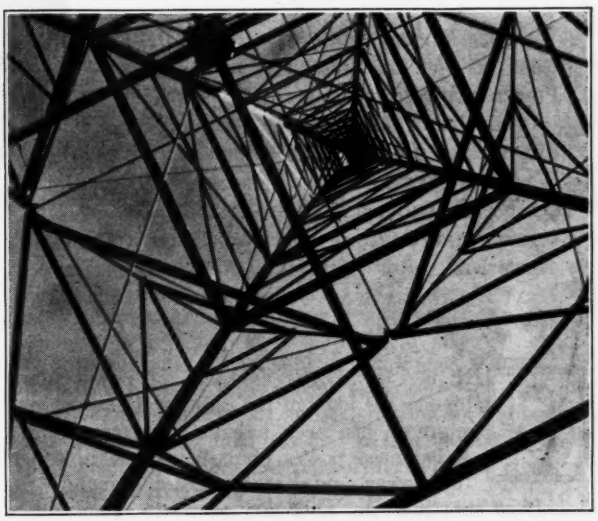
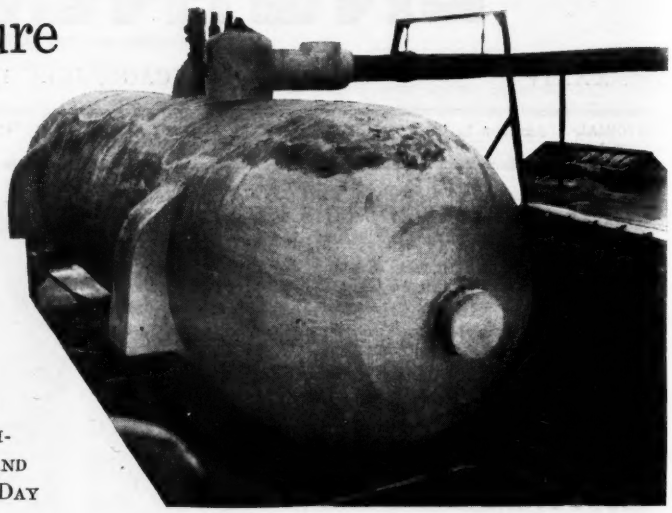


A Queer Point of View

WE HAVE NEVER, in these columns, discussed the question of prohibition nor have we had any desire to do so for two very good reasons; first, because there are plenty of other things to discuss and second, because we have enough to worry about without getting ourselves into more trouble. As a matter of fact prohibition doesn't bother us much and we wouldn't mention it now were it not for the grim example of the evils of bad liquor depicted above. There are limits to one's patience, however, and when we send a photographer out to take a picture of a transmission tower and he comes back with a diagram of a design for a piece of futuristic oilcloth such as you see at the top of this column, by the gods, things have gone too far, and we swear we'll vote dry!

The photographer, despite the damning evidence, has an alibi. He contends that his diagram which we mistook for an example of Hamiltonian coördinates, is a photograph, not of a transmission tower, but of a radio tower. His story is that it is a view he took lying on his back (we believe this part) looking straight up through the center of one of the 300-ft. towers of the new General Electric broadcasting station near Schenectady. He doesn't explain how he came to be lying under this tower but it's a good story and he sticks to it. It's a funny way of looking at a tower but assuming his story to be true, this picture gives us a rather unusual perspective of the subject of oscillators, for this tower combined with its aerial system is an example of one of the types of electric oscillators discussed in this issue's installment of Electricity—What It Is and How It Acts, on page 758.

Balanced Electric and Process Steam Loads in New High-Pressure Power Plant



WALDORF PAPER PRODUCTS CO. OF ST. PAUL GOES TO 650 LB. PRESSURE TO BALANCE POWER AND STEAM LOADS. NEW $750,000 POWER PLANT HAS TWO 13,460-SQ. FT. PULVERIZED COAL FIRED BOILERS WITH WATER WALLS AND AIR HEATERS, 12,000-CU. FT. STEAM ACCUMULATOR AND 4500 KW. OF GENERATING CAPACITY IN TWO UNITS. COMPLETE DETAILS OF EQUIPMENT ARRANGEMENT AND HEAT BALANCE FOR AN OUTPUT OF 225 T. PER DAY

SINCE THE EARLY DAYS of power plant history the ideal of the industrial power plant engineer has been a balanced power plant. A balanced power plant being one in which the power and process steam demands coincide so that it is not necessary to waste steam either to the condenser or atmosphere.

With the extensive development of electric drive, allowing greater latitude in balancing of loads; high steam pressures, giving more by-product power with the same steam flow and the steam accumulator, to smooth out load fluctuations, it became possible to more nearly approach the ideal.

It was not until the new power plant of the Waldorf Paper Products Co. at St. Paul, Minn., designed by Ralph D. Thomas and Associates, consulting engineers of Minneapolis, Minn., was put into service last year, however, that the conditions of the ideal balanced plant could be said to have been fully met. Remarkable as it may seem, this pioneer balanced plant, is in a paper mill where steam and power conditions are unusually severe and fluctuate considerably.

More remarkable perhaps is the fact that the plant was built in the same building replacing the old 175-lb. boilers and engine generator sets without interferring with the output of the mill, principally box board, insulation board, food product containers and labels.

The new power plant consisting principally of two 13,460-sq. ft. Edge Moor, 650-lb. ga., 750-deg. F. boilers with 15,200-sq. ft. air heaters are each fired by two 12,000-lb. per hr. Unipulvos; one geared 1500-kw., 250-v. d.c. and one 3750-kv-a., 480-v. a.c. Westinghouse back-pressure turbo-generators and a. 12,000-cu. ft. Ruths steam accumulator, was built at a total cost of $750,000, an approximate division of the cost being shown in the pie diagram Fig. 3.

$750,000 PLANT SUPPLIES STEAM AND POWER FOR TWO PAPER MACHINES

Savings effected by the new plant consist in the main of formerly purchased power and of coal. On the basis of the increased production realized these are approximately $250,000.00 annually. The plant as installed has capacity sufficient to increase mill production to approximately 250 t. per day or in excess of 50 per cent of the past amount.

The Waldorf Paper Products Co. operates two completely electrified paper machines. In the original power

FIG. 1. WALDORF PAPER PRODUCTS CO. TURBINE ROOM. THE LARGE VALVES NEAR THE END OF THE SWITCHBOARD ARE THE ACCUMULATOR CONTROL VALVES

plant electric power was supplied partly by three engines driving direct-current generators, totaling 1200-kw., and partly by energy purchased from the local public service company.

Originally the steam generating plant consisted of six 175-lb. ga. water tube boilers with a total capacity of 2648-b.hp. set in batteries of two. Four of these boilers were fired with Murphy furnaces and the remaining two, of comparatively recent installation, with multiple retort underfeed stokers.

Paper machine dryers were supplied by the steam exhausted from the engines at a pressure of approximately 23 lb. and this steam was supplemented with high pressure steam reduced to about 45 lb. for the calender rolls. Extensions contemplated in 1927 made it necessary to inquire into the proper procedure for extending or remodeling of the power plant as the possibilities of the plant then in use were exhausted. It was desired to increase the output of the two paper machines with the installation of a third machine contemplated in the near future.

Summer conditions were as follows:

Production	Average	160 t. per day
	Peak day	207 t. per day
Steam	Average	80,000 lb. per hr.
	Peak	110,000 lb. per hr.
Electric Load	Average	2000 kw.
	Peak	2600 kw.

In the investigation consideration was given to the manufacture of electric energy as a by-product in order to dispense entirely with the purchase of power. The savings by this arrangement proved so large that this method of operation was resorted to in the design of the new plant. Usual disadvantages of condensing operation such as heat loss in the cooling water and scaling up of condensers were increased in this case by local conditions. Not being located in the vicinity of a stream of water, all water required by the mill must be pumped from deep wells, so that to the condenser heat losses

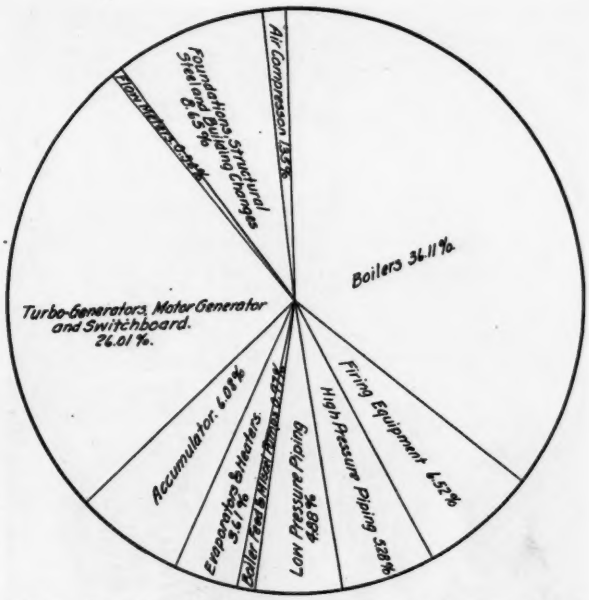

Air Compressor 1.33%
Foundations Structural Steel and Building Changes 2.63%
Piping Miscellaneous 3.22%
Boilers 36.11%
Turbo-Generators, Motor Generator and Switchboard. 26.01%
Accumulator. 6.01%
Evaporators & Heaters 3.47%
Relief Valve & Exhaust Piping 4.33%
Low Pressure Piping 4.08%
High Pressure Piping 5.28%
Firing Equipment 6.52%

FIG. 2. COST DISTRIBUTION OF THE NEW POWER PLANT

there would have to be added the power required to pump the cooling water from the deep wells or the added complication of a cooling pond. This water contains considerable hardness and a total solids of over 20-gr. per gal., so that frequent shutdowns for cleaning condensers would have been necessary.

650 Lb. Proved to Be Best Pressure

To avoid these difficulties the pressure at which condensing operation could be dispensed with and all the required electrical energy be produced as a by-product of the process steam was determined upon. In order to keep this operating pressure as low as possible, an accumulator was included. This accumulator serves as a load balancer by storing the turbine exhaust steam when the steam required for generating the necessary

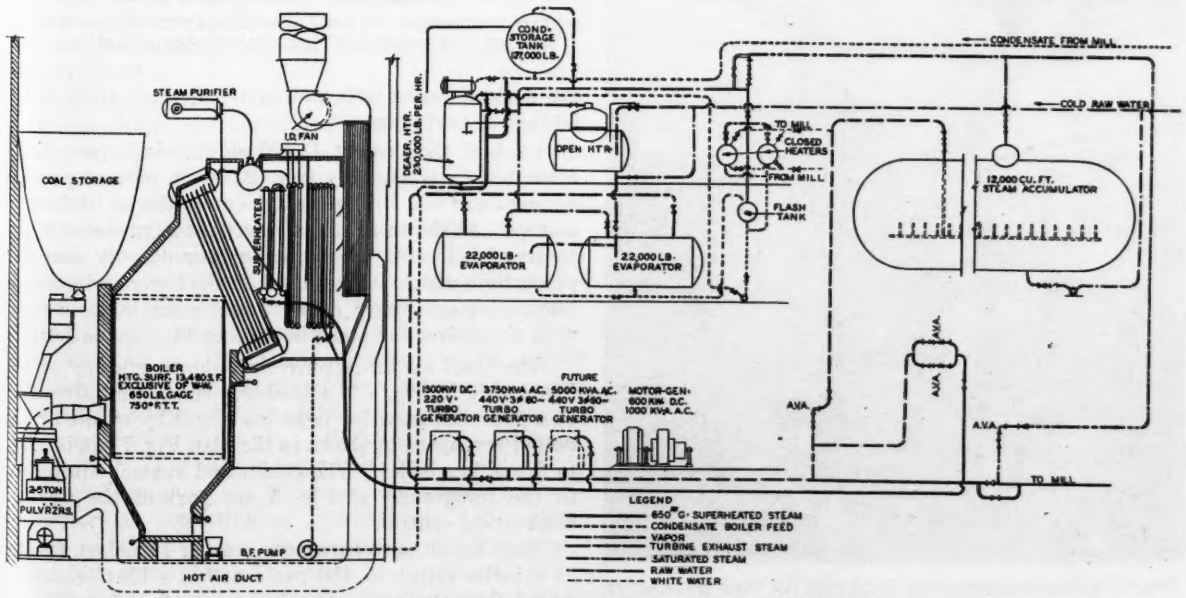


FIG. 3. SCHEMATIC ARRANGEMENT OF THE EQUIPMENT

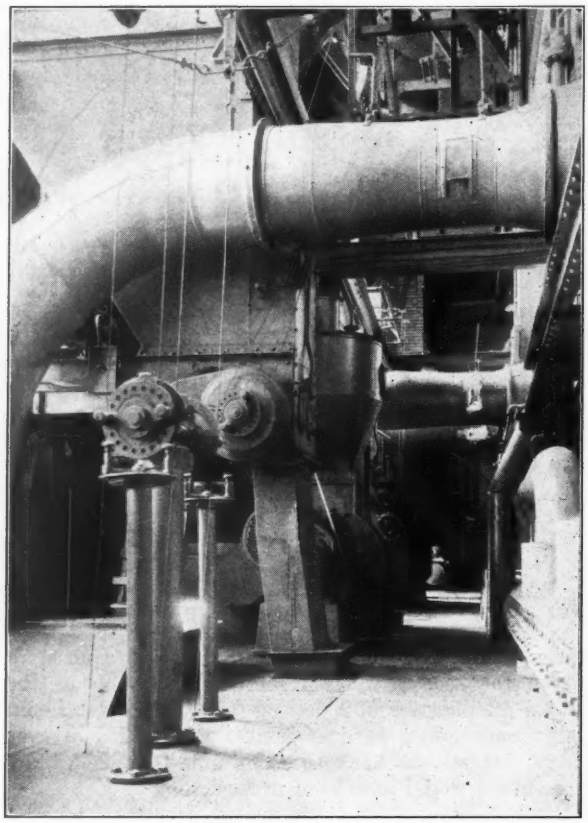


FIG. 4. THE FIRING AISLE WITH THE COMBUSTION CONTROL EQUIPMENT IN THE FOREGROUND

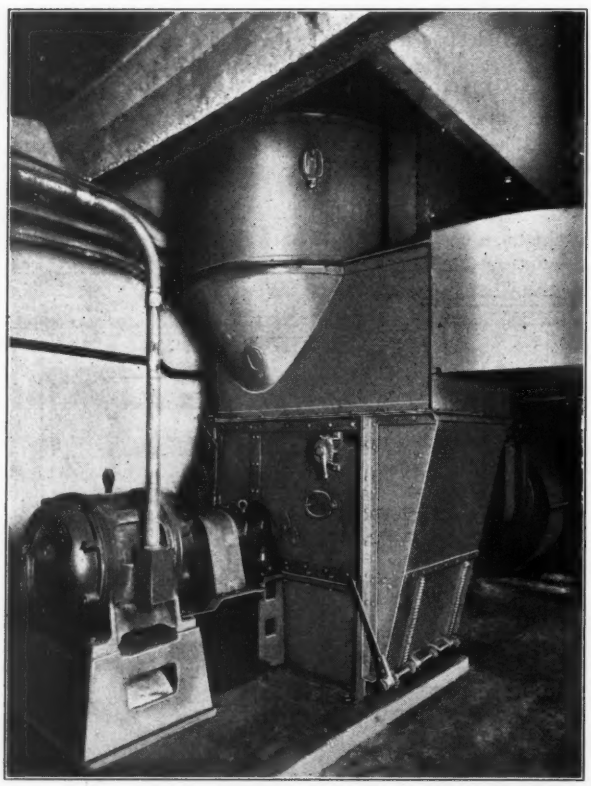


FIG. 5. PULVERIZERS ARE LOCATED ON THE BASEMENT LEVEL

amount of electric energy is larger than the process steam demand, and by releasing low pressure steam under the reverse conditions.

A thorough analysis of the case made by the consulting engineers proved that the pressure of 400 lb. considered by the company in the preliminary investigation was insufficient and that the lowest pressure at which a complete balance could be expected was 650 lb. ga. As a plant of this pressure with an accumulator or load balancer proved to be less in first cost and higher in operating efficiency than a higher pressure plant without an accumulator 650-lb. was decided on as the operating pressure.

Arrangement of the equipment in the new plant is well shown by the plan and cross section Fig. 9 and the photographs Figs. 1, 4, and 5. One boiler is sufficient to supply the steam demand of the plant up to maximum capacity of 180,000 lb. per hr. For future extension beyond this, space has been reserved in the boiler room

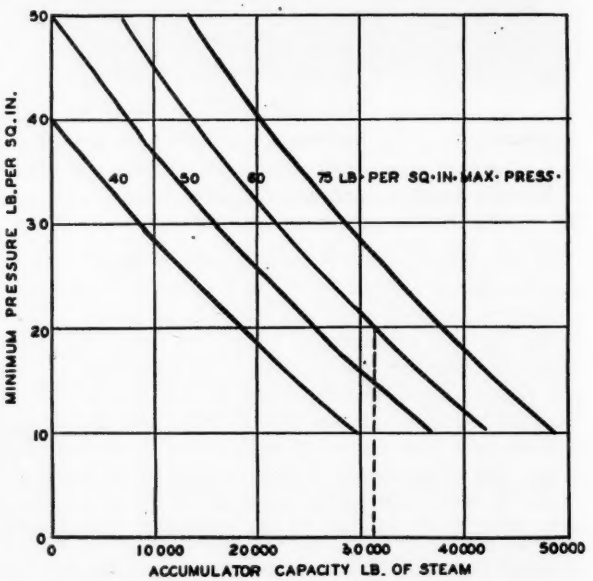


FIG. 6. CAPACITY OF THE ACCUMULATOR WHEN WORKING BETWEEN DIFFERENT PRESSURE LIMITS

for a third boiler unit and in the turbine room for a 5000-kv-a. turbo-generator.

Each of the present 13,460-sq. ft., single-pass Edge Moor boilers is fired by two 12,000 lb. of coal per hr. Strong-Scott Co. Unipulvos driven by 150-hp. induction motors. As shown in the photographs Figs. 4 and 5, the feeders are located on the firing floor directly over the pulverizers which are installed on the lower or basement level, each pulverizer exhaust fan being built integral with the pulverizer and discharging to a single burner.

The small auxiliary pulverizer shown midway of the firing aisle in Fig. 4 is a 1500-lb. per hr. Unipulvo used over the week ends for light loads and by means of the dotted arrangement shown in the plan Fig. 7 can be used to fire either boiler. The cables and control equipment in the foreground of Fig. 4 are part of the Carrick combustion control.

Each boiler has a furnace volume of 11,700 cu. ft. and at a boiler rating of 400 per cent has a heat release of 18,000-B.t.u. per cu. ft. Foster-Wheeler water walls

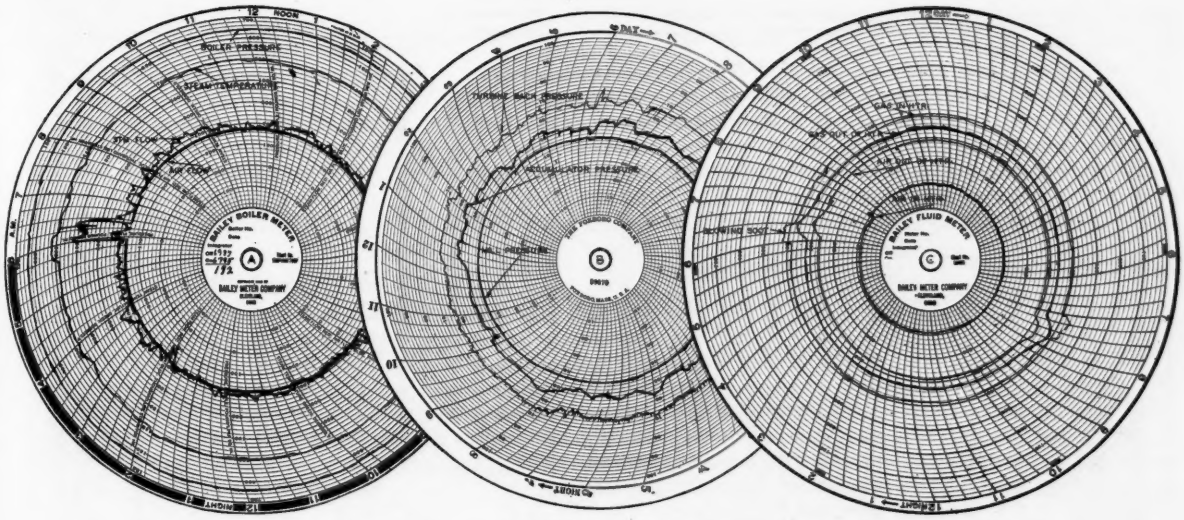


FIG. 7. CHARTS SHOWING THE CONSTANT OPERATING CONDITIONS

totaling 1385 sq. ft. are used on the side walls, back wall and ash pit. The refractory walls and setting are Michael Liptak with McLeod & Henry arches. One Bayley No. 9 induced draft fan driven by a Westinghouse 300-hp., 400-v., squirrel-cage motor is supplied for each boiler. These fans are located on top of the boiler immediately adjacent to the outlet of the 15,200-sq. ft. vertical tubular air heater.

Coal received by rail is elevated by a skip hoist to the top of the boiler room and distributed to the 1000-t. bunker by means of a tram car. Ash is raked from the flat bottom furnace into industrial cars and from them delivered to the same skip hoist. When rebuilding the boiler plant the Beaumont coal handling equipment, bunker and weigh larry from the old plant was retained and left in place to serve the new plant.

Boiler feed pumps, two 375-g.p.m. Camerons designed for a total head of 1795 ft. (780 lb.) and driven by 300-hp. squirrel-cage Westinghouse motors are located in the basement back of the boilers. Evaporators and feedwater heaters are installed on the second and third floors of the turbine room and will be covered later in greater detail.

In the turbine room shown in Fig. 1 are installed two turbo-generators, the accumulator control valves, motor-generator sets, switchboards and air compressors with space provided for a third turbine, probably a 5000-kv-a., 440-v. machine.

The largest generator is a 3750-kv-a., 480-v., 3-phase, 60-cycle, 80-per cent power factor Westinghouse generator driven by a 3600-r.p.m. turbine. This unit shown at the left of Fig. 1 has a 25-kw., 250-v. direct-connected shunt-wound exciter and exhausts at a pressure ranging from 40 to 75 lb. The other unit is a 1500-kw. (max. 1750-kw.) 250-v. d.c., 514-r.p.m. Westinghouse generator driven through gears by a 3542-r.p.m. turbine exhausting at from 60 to 75 lb. gage. Both turbines take steam at 600 lb. ga., 250 dep. F. superheat.

In addition there is a Westinghouse reversible motor-generator set consisting of a 1000-kv-a., 440-v., 900-r.p.m., self-starting synchronous motor and a 600-kw., 250-v. d.c. generator. This machine is visible in the background of Fig. 1 between the direct-current generator and accumulator control valves. The main switchboard is a 15-panel black slate Westinghouse board located along one side of the turbine room.

For pumping water, operating air hoists, and miscellaneous tools, two air compressors are used, one a very old machine now used for standby and which will soon be replaced by a new machine, and a new Ingersol-Rand 16¼ and 26 by 18-in., two-stage, 2100-c.f.m., 110-lb. air compressor driven by a Westinghouse 350-hp., 200-r.p.m., 400-v., 100-per cent power factor synchronous motor. These machines are not shown in the plan of the station Fig. 7 but the new compressor, located underneath the accumulator, is shown in the cross sectional view. In this room is also installed a new 12-panel Condit distribution switchboard.

A color code is used throughout the power plant for piping identification as follows: white water, green; fresh water, blue; condensate, purple; sewerage, black; turbine exhaust, maroon; accumulator discharge, orange; evaporator vapor, yellow; first effect evaporator vapor when operating evaporators double effect, cream; and high-pressure steam, vermillion.

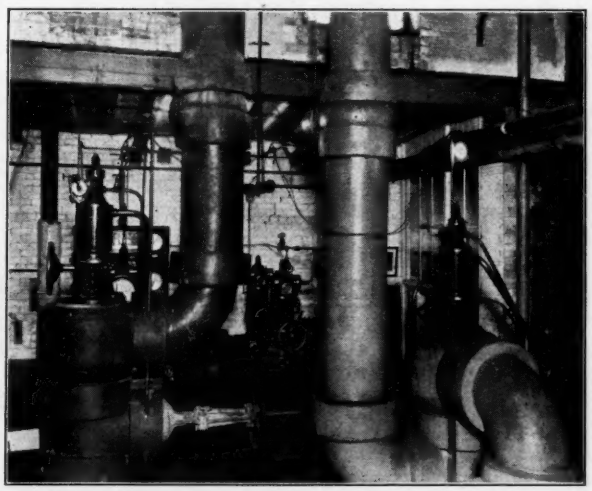


FIG. 8. CLOSE UP OF THE AUTOMATIC ACCUMULATOR CONTROL VALVES

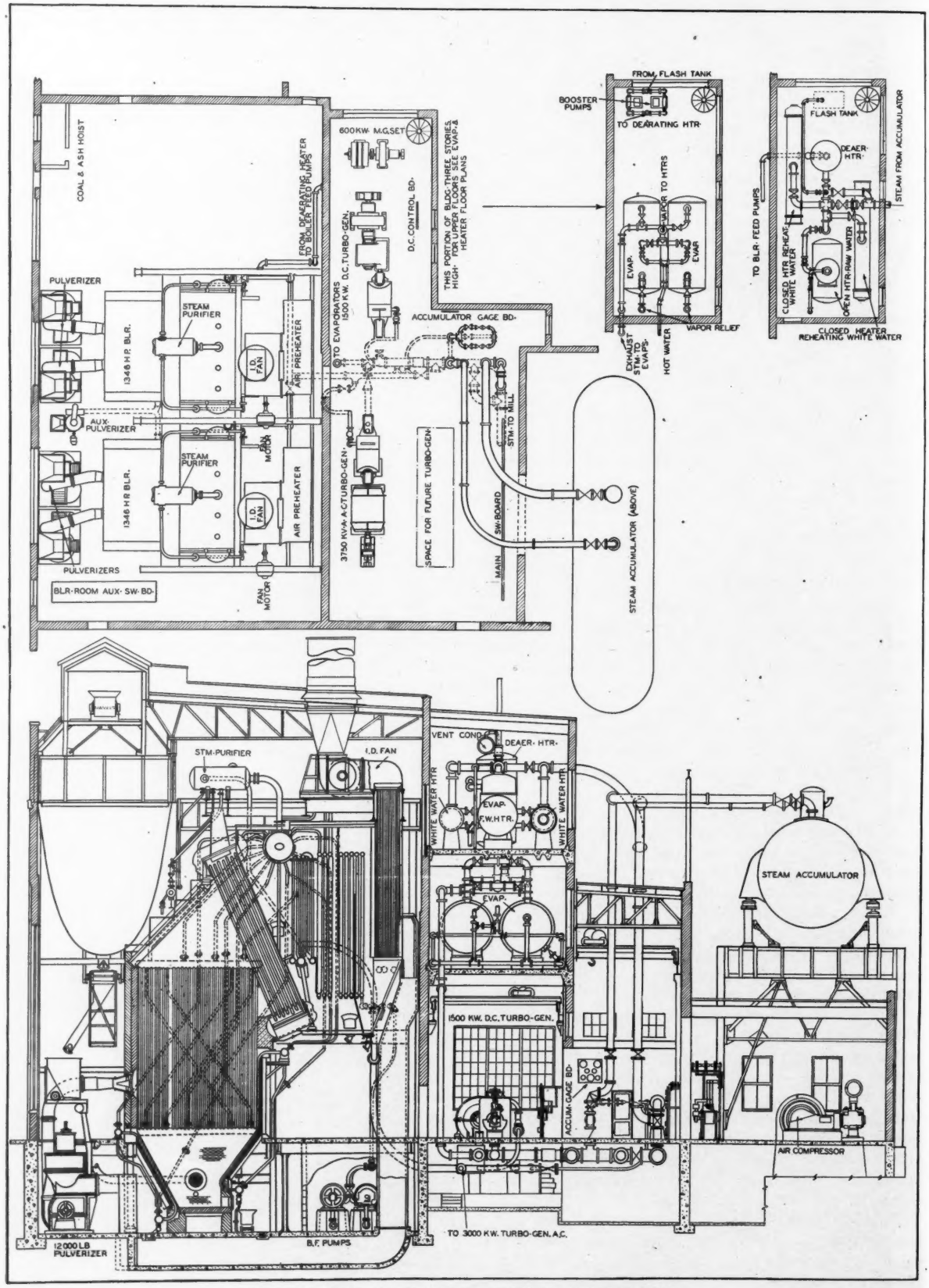


FIG. 9. PLAN AND CROSS SECTION OF THE STATION

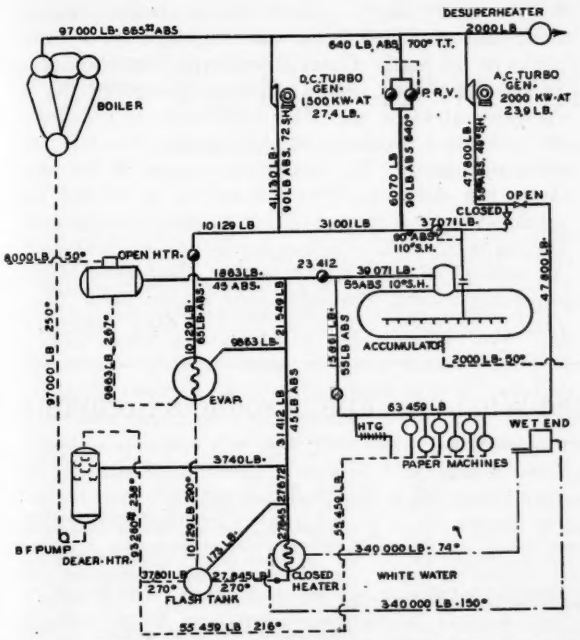


FIG. 10. HEAT BALANCE BASED ON AVERAGE HOURLY REQUIREMENTS FOR A DAILY OUTPUT OF 225 T.

For equalizing the boiler load a Ruth's steam accumulator 16 ft. in diameter and 65 ft. long with a volume of 12,000 cu. ft. was installed. This accumulator shown installed in the headpiece is built for a maximum operating pressure of 75 lb. Different steam pressures are needed for the paper machines depending upon the type of board manufactured, so that the accumulator works between different pressures and so has a variable capacity. Figure 6 shows the capacity for 75, 60, 50 and 40 lb. maximum pressures and different minimum pressures. Between 75 and 15 lb. pressure, the capacity is 44,000 lb. of steam but when the lower pressure is raised to 45 lb. the capacity drops to 25,000 lb.

The steam and feedwater cycle of the plant is best shown in diagrammatic form by Fig. 3. Exhaust steam from the turbines is split between the evaporators, accumulator and mill. Vapor from the evaporators is used for the open evaporator feed heater, the deaerating feedwater heater, steam sealing for the condensate storage tank and in the closed heaters supplying white water for the mill. These heaters are in effect the evaporator condensers.

Boiler No.	1	1	1	1	2	2
For Week Ending	5-18-29	5-25-29	6-8-29	6-29-29	10-26-29	11-2-29
Hours Operation	144	144	144	144	24	24
Water Evaporated	12,413,400	11,617,800	11,902,600	12,527,600	2,590,625 (24 hr. av.)	2,575,250 (24 hr. av.)
Coal Burned	1,234,000	1,180,000	1,154,000	1,184,000	253,383	256,183
Actual Evaporation	10.06	9.85	10.314	10.561	10.62	10.46
Factor of Evap.	1.1707	1.165	1.1717	1.1778	1.181	1.166
Evap. F & A 212°	11.77	11.46	12.085	12.356	12.55	12.45
Steam Fresh	641	646	640	637	640	645
Steam Temp.	720°	715°	722°	731°	724°	736°
Deg. Superheat	224°	219°	228°	236°	228°	239°
Feed Water Temp.	255°	256°	255°	255°	247°	247°
Temp. Air In	98°	100°	102°	105°	98°	93°
Temp. Air Out	301°	299°	306°	317°	335°	328°
Temp. Gas. In	400°	391°	421°	415°	435°	425°
Temp. Gas. Out	332°	318°	334°	360°	346°	347°
Coal	Wva. Splint	Ill. & Wva. Sp	Spl. & Poca.	R & P	R. & P.	R. & P.
F.C.	52.87	50.52	53.07	56.30	60.05	60.15
Vol.	34.82	34.50	34.55	29.65	28.85	28.50
Ash	7.52	9.00	7.95	7.50	8.50	7.75
Mois.	4.79	5.98	4.43	4.55	2.60	3.90
Sul.	2.13	1.86	1.83	1.21	1.98	1.18
B.T.U. as Fired	13,000	12,700	13,450	13,756	13,865	13,861
Avg. Lbs. Steam/Hr.	86,500	81,000	83,000	88,000	112,500	111,500
Avg. Rating	210%	202%	207%	220%	280%	285%
Max. Rating			260%	300%	355%	310%
Operating Efficiency	87.9%	87.5%	87.2%	86.6%	87.7%	87.1%
Guaranteed Efficiency	86.6%	86.6%	86.6%	86.7%	86.6%	86.6%
C Op					14.0%	14.0%
Heat Release					13,600	13,700

FIG. 11. BOILER EFFICIENCY RESULTS TAKEN FROM THE OPERATION RECORDS

Condensate from the mill returns through the vent condenser direct to the 230,000-lb. per hr. Cochrane deaerating from which the boiler feed pumps take their suction. All makeup is evaporated, the evaporator feed passing through a Griscom-Russell open heater. The Griscom-Russell evaporators have a capacity of 22,000 lb. per hr. each. Drains from the evaporators are vented through a flash tank and together with the drains from the closed heaters are pumped to the deaerating heater to be used for boiler feed makeup.

Details of the arrangement and the heat balance for a daily output of 225-t. of paper are given in the flow diagram Fig. 10. Under these conditions 97,000 lb. of steam are generated in the boiler at a pressure of 650 lb. ga. and 750 deg. F. total temperature. Steam conditions at the turbine throttle and at the A.V.A. (accumulator control valves) are 640 lb. abs. and 700 deg. F. total temperature. Of this steam, 2000 lb. is passed through a small desuperheater and used in corrugators at a pressure of 160 lb. ga. while 47,800 lb. is supplied to the alternating-current turbo-generator from which,

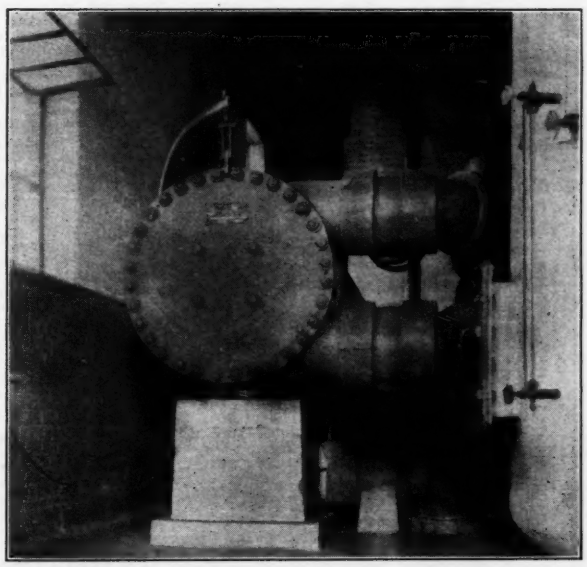


FIG. 12. ONE OF THE WHITE WATER HEATERS ON THE THIRD FLOOR

after generating 2000 kw., it is exhausted at a pressure of 55 lb. abs. directly to the mill line.

To the direct-current turbo-generator, 41,130 lb. is supplied and this after producing 1500 kw. is exhausted at 90 lb. abs. to supply 10,129 lb. through a throttling valve to the evaporators. The balance, 31,001 lb. is mixed with 6070 lb. reduced through one of the A.V.A. reducing valves so that 37,071 lb. at a pressure of 90 lb. abs. and 110 deg. F. superheat are supplied to the accumulator while 2000 lb. of raw cold water are fed to, and evaporated in the accumulator to remove the greater portion of the superheat.

A total of 39,071 lb. is therefore discharged from the accumulator at a pressure of 55 lb. abs. and 10 deg. F. superheat. Of this, 15,861 lb. is supplied to the paper mill line, where it joins the 47,880 lb. exhausted from the alternating-current turbo-generator to make up 63,459 lb. required by the paper machine dryers. The remainder, or 23,412 lb., is discharged through a reduc-

ing valve to a low-pressure header at a pressure of 45 lb. abs. This header received, besides the above-mentioned 23,412 lb., 9863 lb. of evaporator vapor (the evaporator feed is made up of 8000 lb. of raw cold water and 1863 lb. of steam from the 45 lb. header) and 173 lb. from the flash tank, making a total into this header of 33,448 lb. This is distributed as follows: 1863 lb. to the evaporator feed water heater, 3740 lb. to the deaerating heater and 27,845 lb. to the closed heater. The latter, heat part of the paper machine white water from 74 to 150 deg. F.

White water heater drains of 27,845 lb. together with the 10,129 lb. of steam condensed in the evaporators, less the 173 lb. flashed in the tank to bring the evaporator condensate to the temperature of the white water heater drains, join the drains from the paper machines making a total of 93,280 lb. delivered to the deaerating heater. Here 3740 lb. of steam is added from the low-pressure header to supply the required boiler feed of 97,000 lb.

Without the accumulator the installed boiler capacity would of necessity have been materially greater due to the large peaks in the steam demand. In this case the peaks are absorbed by the accumulator. The pressure would also have to be considerably higher to produce at all times all the required electric energy from the process steam.

The accumulator regulates the pressures within close limits as can be seen from the charts reproduced in Fig. 8. The boiler chart A shows that the boiler pressure is kept constant at 640 lb. ga. and that there are no decided peaks in the load. Chart B indicates that the pressure in the mill supply line is uniform throughout the days operation at 44 lb. ga. This uniformity in condition of the boiler and process steam has resulted in better operating efficiencies. The increased pressure of the process steam has made possible a speeding up of the paper machines with a corresponding increase in production. Drying is more uniform and breaks are less frequent.

Savings effected with this new plant have exceeded expectations and the total coal consumption for the present increased output of 225-t. is 20-t. per day less than the consumption for an output of 160-t. with the old plant. In addition all electric power is made as a by-product. Some of the operating results taken from the operating records of the boiler room are shown in Fig. 10.

This plant, which sets a new standard for industrial power plants, was designed in the offices of Ralph D. Thomas, consulting engineer, Minneapolis, under the direction of J. V. Edeskuty. The installation was supervised by the Waldorf Paper Products Co.'s own organization, with A. J. Waldorf, general superintendent, and L. A. Breneman, who was at that time assistant general superintendent. H. N. Peterson acted as resident engineer for the designers. N. H. Sandberg, who is now assistant general superintendent and chief engineer, was master mechanic at the time of installation.

Principal Power Plant Equipment of the Waldorf Paper Products Company

BOILER ROOM

2 Edge Moor Iron Co. 13,460-sq. ft., 4-unit, single pass, 650-lb. ga. boilers; maximum continuous steam capacity 180,000-lb. per hr., furnace volume 11,700-cu. ft., heat release at 400 per cent rating, 18,000-B.t.u. per cu. ft.
2 Foster-Wheeler Corp. superheaters designed to give a total steam temperature of 750 deg. F. at the superheater outlet.
2 Edge Moor Iron Co. 15,200-sq. ft. tubular air heaters.
4 Strong-Scott Mfg. Co. Unipulvo pulverizers with a normal capacity of 12,000-lb. per hr., and with an over load capacity of 15,000-lb. per hr. each. Each pulverizer driven by a 150-hp. Westinghouse, 440-v. induction motor.
1 Strong-Scott Mfg. Co. Unipulvo auxiliary pulverizer with a capacity of 1500 lb. per hr. Driven by 20-hp., 440-v. Westinghouse motor.
6 Strong-Scott Mfg. Co. Votex burners, 2 large and 1 auxiliary burner for each boiler.
2 Bayley Blower Co. No. 9, type E, induced draft fans each driven by a Westinghouse 300-hp., 440-v., induction motor.
2 Ingersoll-Rand Co., 375-g.p.m., total head 1795-ft., Cameron boiler feed pumps each driven by a 300-hp., 440-v. Westinghouse induction motor.
2 Wm. Bros Boiler & Mfg. Co. stacks 7-ft. diameter and 50-ft. high.
Water walls total 1385-sq. ft. per boiler ..... Foster Wheeler Co.
Boiler settings..... Michael Liptak Co.
Arches ..... McLeod & Henry Co.
Excess pressure regulators..... Mercon Regulator Co.
Safety valves ..... Consolidated Ashcroft Hancock Co.
Combustion control.. Carrick Engr. Co.
Steam purifier..... Cochrane Corp.
Non-return valves ..... Edward Valve & Mfg. Co.
Coal and ash handling equipment... R. H. Beaumont & Co.
Ducts, breechings, soot hoppers, boiler platforms ..... Wm. Bros Boiler & Mfg. Co.
Pressure gages ..... Consolidated Ashcroft Hancock Co.
Soot blowers ..... Diamond Power Specialty Co.
Feed water regulators, Copes..... Northern Equipment Co.
Blow-off valves.... Yarnell-Waring Co.
Boilers and firing equipment contract complete with equipment installed ..... Robinson, Carey & Sands Co.

TURBINE ROOM

1 Westinghouse Elec. & Mfg. Co. 1500-kw., (maximum capacity 1750-kw.) 250-v. d.c., 514-r.p.m. generator driven through gears by a 1500-kw, 3540-r.p.m. turbine taking steam at 600-lb. ga., 750 deg. F. and exhausting against a back pressure of from 60-lb. to 75-lb. ga.
1 Westinghouse Elec. & Mfg. Co. 3750-kv-a., 3-phase, 60-cycle, 480-v., 80 per cent power factor, 3600-r.p.m. generator driven by a turbine taking steam at 600-lb. ga., 750-deg. F. exhausting at a back pressure of from 40-lb. to 75-lb. Direct connected shunt wound exciter, 25 kw.
1 General Electric Co. 1580-sq. ft. generator air cooler.
1 Westinghouse reversible motor generator set with a 1000-kv-a., 3-phase, 60-cycle, 440-v., 900-r.p.m. self-starting synchronous motor and a 600-kw., 250-v. d.c. generator.
Control switchboard ..... Westinghouse Electric & Mfg. Co.
Distribution switchboard ..... Condit Electrical Mfg. Co.
Crane..... Northern Crane Co.

EVAPORATORS AND HEAT EXCHANGERS

1 Ruths Steam Storage, Inc., steam accumulator and A.V.A. control valves. Accumulator 16-ft. in diameter and 65-ft. long with a volume of 12,000-cu. ft. Designed for 75-lb. working pressure, operating pressure 70 to 44-lb. ga.
Accumulator insulation ..... Johns-Manville Corp.
2 Griscom-Russell Co. No. 9 horizontal bent tube evaporators with a capacity of 22,000-lb. per hour. Tubes designed for working pressure of 100-lb. per sq. in., shell for 30-lb. per sq. in.
1 Griscom-Russell Co. Massillon No. 18 evaporator feed open heater.
2 Griscom-Russell Co. No. 35-16-240, 2-pass, style L, horizontal vapor condensers and white water heaters designed for working pressure of 30-lb.
1 Griscom-Russell Co. 36-in. by 72-in. flash tank.
1 Cochrane Corp. No. 672 deaerating heater with a capacity of 230,000-lb. per hour working pressure, 30-lb. per sq. ft. ga.
1 Cochrane Corp. No. 221200 vent condenser.
1 Griscom-Russell Co. multiwhirl gland water cooler.
Booster pumps. Buffalo Steam Pump Co.

MISCELLANEOUS

1 Ingersoll-Rand Co. 2100-c.f.m., 110-lb., 2-stage air compressor driven by a Westinghouse 350-hp., 200-r.p.m., 440-v., 100 per cent power factor synchronous motor.
Piping... Crane Co. / Midwest Piping & Supply Co.
Piping installed by..... Donovan Construction Co.
Valves..... Crane Co. / Edward Valve & Mfg. Co. / Walworth Co.
Insulation ..... Philip Carey Co.
Steam flow meters.... Bailey Meter Co.
Temperature recorders ..... Bailey Meter Co.
Pressure recorder..... Bailey Meter Co.
Draft gages..... Bailey Meter Co.
Indicating pressure gages..... Consolidated Ashcroft Hancock Co.

Steam Turbine Economies in Power Generation*

Turbine Size Based on Use Factor, Availability, Heat Cycle and Heat Balance. Sizes, Pressures and Temperatures for Industrial Plants. By A. G. Christie**

DEVELOPMENT of the large steam turbine has been stimulated more by the demand for capacity than for improved efficiency, although satisfactory gains in economy have been achieved with increase in size. Trend of steam turbine development in America has been progressively towards units of large capacity, Fig. 1 showing the progress in operating conditions of one turbine builder over period of years.

Operating conditions vary with steam pressure, temperature, exhaust conditions, cost of fuel, heat cycle of the plant and with use factor, which is the ratio of the total annual output in kilowatt-hours, to the normal rating of the turbine in kilowatts multiplied by the total hours per year, i.e. 8760.

Large turbines can be built for higher engine efficiencies† than small units, which leads to lower operating costs. Figure 2 shows the gain in efficiency between two notable Westinghouse turbines built four years apart.

In choosing new turbines probable increase in demand enters, as too small units may necessitate frequent plant additions, while too large units may require operation at low use factor when first installed. Duplicate units permit interchangeability and small investment in spare parts but, as operating reliability increases, these advantages become of less value. Units of current design at the time of each extension and often of progressively increasing size and efficiency are usually installed in American stations, Fig. 3 showing the improvement in performance for five Allis-Chalmers turbines furnished consecutively in the same central station over a period of eight years. The constant rate of heat consumption of No. 5 unit over a wide range of load is characteristic of the trend of design in large turbines.

Capacity of a new unit should be such that in case of outage, the remaining units of the system can safely carry the load, recent practice being one-sixth to one-fourth of the system's total capacity.

Peak Load Turbines

American engineers prefer to install units that are available at all times for steady operation so that they may serve in emergencies in place of one of the main units. They believe that added furnace volume is the cheapest method of providing additional steam-generating capacity for peak load service; that peak load boiler operation at high ratings is economical. Availability of high-pressure steam for peak loads favors installation of high-pressure turbines with extreme capacity above their most economical load to utilize this steam. Unit No. 5, Fig. 3, has best efficiency at 62,000 kw. but it can operate with little increase in heat consumption up to its rated capacity of 115,000 kw.

Certain data on modern turbines which will assist in their economic selection are presented in Table I, showing floor space, weight, efficiencies and first costs for large units.

Reserve Capacity

A single large unit, so expensive that adequate reserve to replace its outage is not provided, leads to operating difficulties.

TABLE I. ECONOMIC TURBINE DATA

Rating in 1000 kw.	Floor space of unit sq.ft. per 1000 kw.	Wt. of unit lb. per kw.	Eng Effy. for best kw. output Cond. % #	Non-Condensing % ##	Cost per kw. + Cond. $	Non-Condensing. $
			For 3,600 r.p.m.			
0.5	210	53.0	59.0	53.0	39.00	26.50
1.0	137	39.5	65.0	59.0	27.60	19.00
1.5	112	34.0	67.5	60.7	24.40	15.00
2.0	97	31.0	69.0	61.6	22.40	13.00
2.5	87	29.0	70.0	62.1	20.80	.....
3.0	80	27.7	71.0	62.5	19.60	.....
3.5	75	26.3	71.5	62.6	19.00	.....
4.0	70	25.2	72.2	62.7	18.20	.....
5.0	62	23.5	73.0	....	17.30	.....
6.0	56	22.3	73.7	....	16.50	.....
7.0	52	21.2	74.3	....	16.20	.....
8.0	48	20.4	74.8	....	16.10	.....
9.0	46	19.6	75.2	....	16.00	.....
10.0	44	19.0	75.5	....	16.00	.....
			For 1,800 r.p.m. ###			
10	60.0	29.5	74.6	....	17.50	.....
15	53.5	26.2	75.5	....	16.50	.....
20	49.0	24.1	76.3	....	15.70	.....
25	45.0	22.7	76.8	....	14.80	.....
30	41.8	21.6	77.3	....	14.10	.....
35	38.7	20.7	77.7	....	13.70	.....
40	36.0	19.8	77.9	....	13.20	.....
45	33.2	19.2	78.2	....	12.70	.....
50	31.0	18.3	78.5	....	12.30	.....
55	29.0	17.7	78.6	....	12.10	.....
60	27.5	17.1	78.7	....	11.80	.....
65	26.2	16.4	78.8	....	11.40	.....
70	25.0	15.8	78.9	....	11.20	.....
75	24.4	15.4	79.0	....	11.10	.....
80	23.9	14.8	79.2	....	11.00	.....
90	23.5	13.9	79.3	....	11.00	.....
100	23.5	13.0	79.5	....	11.00	.....

‡300 lb.g., 600 deg.F., 28.5 in. vac.
‡‡250 lb.g., 550 deg.F., no vac.
‡‡‡450 lb.g., 750 deg.F., 29 in. vac.
+ Prices for bare turbine and generator in U. S. A., delivered and erected. No auxiliaries or exciters, 400 lb.g., 725 deg.F., 29 in. vac. for condensing.

Enough capacity in the same or in other interconnected stations should be held in reserve to carry the load in case of outage of the largest unit, though this reserve margin is sometimes sacrificed at the time of maximum annual short and sharp peaks. As a result of improvements in service availability and reliability, most American systems now carry equipment in reserve to the extent of 20 to 25 per cent of the system demand.

*From a paper before the World Power Conference, Berlin, June, 1930.
**Professor of Mechanical Engineering, Johns Hopkins University, Baltimore, Md.
†Engine efficiency is defined as the ratio of the heat turned into work at the coupling or at generator terminals per pound of steam supplied, to the heat available per pound from adiabatic expansion on the Rankine cycle between initial throttle steam conditions and exhaust pressure.

Because outage from any cause during periods of demand necessitates added reserve capacity, central station engineers sacrifice some measure of efficiency to secure rugged and dependable turbines. Reports of the Prime Movers Committee of the N. E. L. A. indicate that for 1928-29 the availability factor of 207 turbines of 20,000 kw. capacity and above, averaged 90.31 per cent. The major causes of turbine outages are blade troubles but developments in design and construction give promise of reduction in outages from this cause.

Steam Pressures and Temperatures

Improvements in design of high-pressure equipment and lowered heat consumption, from high steam pressure and temperature with reheating, have lessened the

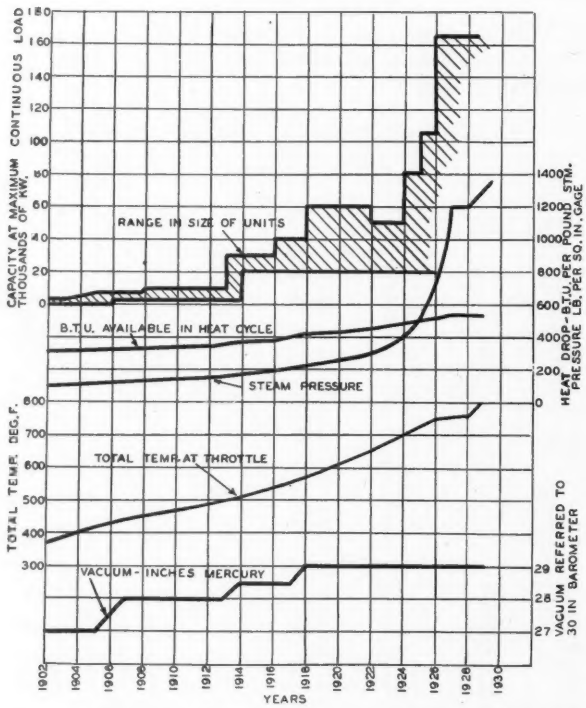

CAPACITY AT MAXIMUM CONTINUOUS LOAD THOUSANDS OF KW.
RANGE IN SIZE OF UNITS
B.T.U. AVAILABLE IN HEAT CYCLE
STEAM PRESSURE
HEAT DROP-B.T.U. PER POUND STM. PRESSURE LB. PER SQ. IN. GAGE
TOTAL TEMP. DEG. F.
TOTAL TEMP. AT THROTTLE
VACUUM - INCHES MERCURY
VACUUM REFERRED TO 30 IN. BAROMETER
YEARS

FIG. 1. PROGRESS IN OPERATING CONDITIONS FROM CONSTRUCTION DATA OF WESTIGHOUSE ELEC. & MFG. CO.

size of boilers, furnaces and condensers, so that total cost of a plant for 1200 to 1500 lb. per sq. in. pressure is said to exceed that of a 450-lb. plant by not more than 5 per cent. Eventually, a 1500-lb. plant will cost no more, or at least little more, than one for lower pressure.

Tests indicate that in large turbine units the high-pressure section, receiving steam at 1200 lb., can be designed to give nearly as high engine efficiency as its low-pressure section and that compound units can be built to give over all engine efficiencies of 78 per cent based on kilowatt output.

Initial steam temperatures in America have not, in general, exceeded 750 deg. F. With this temperature limit, steam pressure above 450 lb. with a modern high efficiency turbine results in excessive moisture at the last blades of the turbine, rapid erosion and lowered efficiency of the unit.

Engineers are, therefore, limiting the moisture content of exhaust steam to 10 per cent, either increased steam temperatures or interstage reheating being employed with pressure of 500 lb. or higher.

Rapid decrease in tensile strength of ordinary steels at temperatures above 750 deg. F. and troubles from "creep," have made engineers question the use of such steels at these higher temperatures but recent experiences with certain alloy steels now warrant their safe use at high temperatures. It is proposed to allow such stresses in the design of turbines for high temperature, that "creep" will not exceed one one-hundredth of one per cent a year.

Increased steam temperature tends to increase the cost of superheaters, main steam piping and the high pressure section of the turbine but total increase in cost, even using special alloys should be less than the cost of reheaters and the use of higher superheat will lead to a simpler station.

Steam Reheating and Regenerative Feed Water Heating

Reheating is sometimes by a special reheating boiler, sometimes by a live steam reheater, which has simpler piping and less first cost, though the temperature leaving such a reheater is lower than the initial steam temperature. Live steam reheating at 600 lb. per sq. in., for best results at 10 to 20 per cent of the initial pressure, gives a gain of less than 2 per cent over operation without a reheater.

Thermal advantages of regenerative feed heating are now generally recognized. Usually the evaporator system to furnish distilled make-up water for boiler feed, forms a portion of the bleeder system, steam for the vaporator being taken from one of the bleeder points and the evaporator condenser used to heat the feed water, or one of the lower bleeder heaters is used as an evaporator condenser. The best stations are said to require only 0.5 per cent evaporated make-up but usual allowance in selecting evaporators is 1½ to 2 per cent.

Bleeder heaters above three can be economically justified only where use factors, fuel costs, or both, are high. More bleeder heaters are added when air preheaters alone are used than when an economizer is installed.

Pressure drop from the extraction point to the bleeder heater varies from 3 per cent on high-pressure heaters to 10 per cent on the lowest pressure heater. Experience has shown that, contrary to early ideas, it is economical to bleed superheated steam from the turbine to heat feed water, final water temperature being 2 to 20 deg. F. above saturation temperature. With saturated steam, the final temperature of the feedwater is lower than steam in the heater by 5 to 10 deg. F. Water velocities in heater tubes vary from 4 to 6 ft. per sec. with pressure drops through the heater of 4 to 12 lb. per sq. in. Heat transfer rates vary from 400 to 700 B.t.u. per sq. ft. per hr. per deg. F. of arithmetical mean temperature difference, the higher transfer rates being found in high-pressure bleeder heaters when the water velocities in the tubes are high.

Moisture in the flowing steam exists as minute droplets but is concentrated to some extent by centrifugal force at the moving blade tips. Some new turbines have drainage grooves to remove a portion of this moisture with some gain in efficiency and decrease in blade erosion.

Estimates and actual performances have shown a gain in economy to be expected from reheating, for initial steam pressures at 600 lb. and higher, of 6 to 8 per cent largely from the improvement of turbine efficiency in the low-pressure stages.

Analysis of Reheating

Analysis of the gains from reheating steam after partial expansion has been furnished by engineers of the Allis-Chalmers Co. If additional energy rendered available by reheating be divided by the heat added during reheating, it gives the possible efficiency for the reheat process and, if added work done by the turbine because of reheating be divided by the heat added during reheating it gives actual efficiency at which the added heat is used.

Analysis have been worked out for 600 lb., 1200 lb. and 2000 lb., initial and reheated temperatures being 800 deg. F. and vacuum 29 in. in all cases, with no allowance for reheat factors, moisture correction or pressure drop through the reheater. For 600 lb., reheat was considered at pressures of 300 to 50 lb.; for 1200 lb., reheat at 600 lb. to 100 lb.; for 2000 lb., reheat at 1200 lb. to 200 lb. For each case, values were determined for 100 per cent and for 80 per cent engine efficiency at the coupling.

Efficiency of reheat use = (work from steam after reheat — work without heat) ÷ heat added by reheater. Thermal efficiency = (work done in both sections of turbine) ÷ (heat from boiler and reheater — heat of liquid at feedwater temperature).

Per cent of total heat added in reheater = (B.t.u. from reheater) ÷ (B.t.u. from boiler above heat of liquid of feedwater + B.t.u. from reheater). Curves for 1200 lb. are shown in Fig. 4.

For simplicity the same overall efficiency was assumed for straight condensing, reheat and extraction turbines. If allowance were made for moisture effect

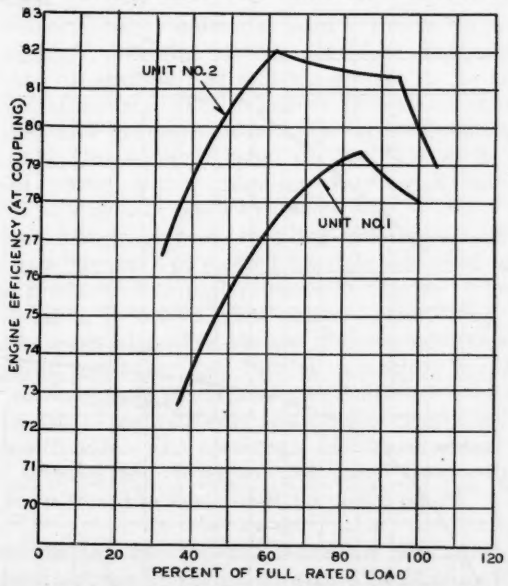


FIG. 2. SINGLE CYLINDER WESTINGHOUSE TURBINE EFFICIENCIES. NO. 1 CAHOKIA, 40,000-KW. OF 1924, 300 LB., 670 DEG., 29 IN. MULTIPLE FLOW LOW-PRESSURE BLADING, ANNULUS, OF LAST ROW OF BLADES, 84.0 SQ. FT. NO. 2 LAKESIDE, 60,000 KW. OF 1928, 290 LB., 700 DEG., 29-IN. STRAIGHT REACTION LOW-PRESSURE BLADING, ANNULUS OF LAST ROW OF BLADES 83.1 SQ. FT.

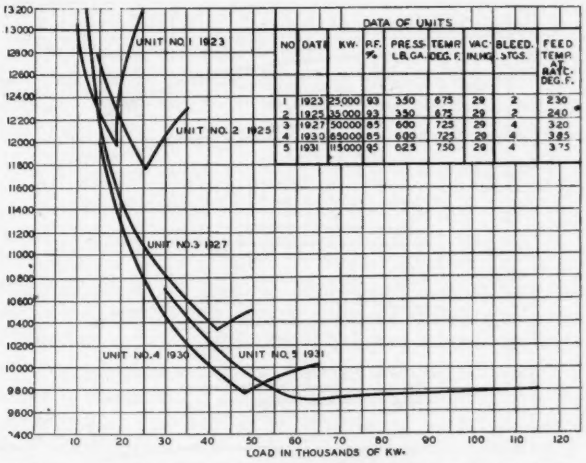


FIG. 3. IMPROVEMENT IN STEAM TURBINE PERFORMANCE, 1923-1931

in low-pressure sections, efficiencies at which reheat is used for 80 per cent engine efficiency would be increased.

For reheating at high pressures, efficiency of use of reheat is high and the amount supplied low. For low pressures the reverse is true.

Since thermal efficiency of a reheat cycle depends on both amount of reheat and efficiency of its use, some reheat pressure will show highest thermal efficiency for given operating conditions, as indicated by the crest in the thermal efficiency curves. With extracting and reheating, this maximum comes when reheating at 30 per cent of initial pressure, for 80 per cent engine efficiency; this is somewhat higher than current practice, which is to reheat at 20 to 25 per cent of initial pressure.

Curves for 600 and for 2000 lb. are of the same general shape, showing a gain from extraction of about the same per cent but maximum gains in thermal efficiency of 1.25 per cent for 600 lb., 1 per cent for 1200 and 0.8 per cent for 2000 lb. at 80 per cent engine efficiency.

Efficiency of use of reheat increases with reheat pressure and, for 80 per cent engine efficiency, is substantially constant for a given ratio of reheat to initial pressures, regardless of the initial pressure.

Thermal efficiency for non reheat is, however, higher, the higher the pressure, so that maximum thermal efficiencies with extraction and reheat are: For 600 lb., 36 per cent; for 1200 lb., 37.5 per cent; for 2000 lb., 39 per cent, suggesting that the gain may justify the use of 2000 lb. pressure, rather than the present practice of 1200 lb.

Economic Selection of a Large Steam Turbine

Demand for units that will give the best performance in heat per kilowatt-hour leads to particular care in the recovery of all waste heat through the use of generator air coolers, oil coolers, and inter- and after-condensers on steam jet air pumps, also to the most economical arrangement of bleeders and evaporators. Condensers are designed for maximum vacuum with the water at hand and plants are located for large supplies of cold circulating water. It has been found economical at times to use as much as 120 lb. of cooling water per pound of steam condensed.

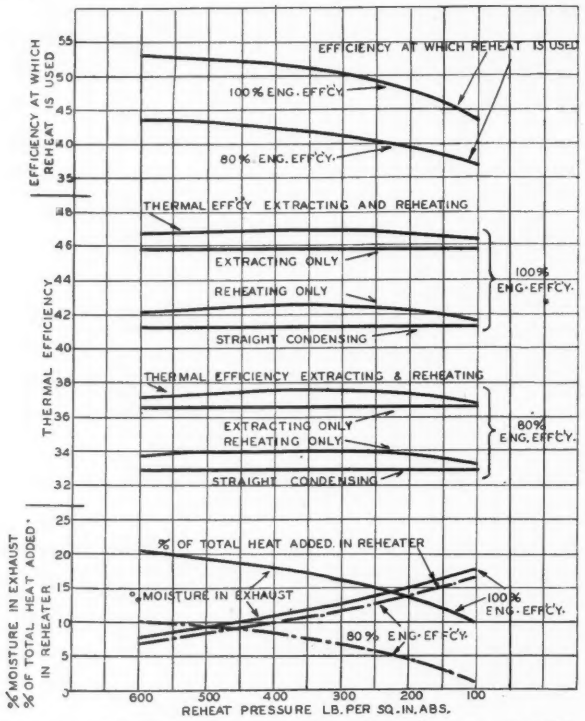


FIG. 4. ANALYSIS OF REHEATING FOR 1200 LB., 800 DEG. F. AT THROTTLE; REHEATING AT VARIOUS PRESSURES TO 800 DEG. F.; 29-IN. VACUUM. FOR IDEAL TURBINE OF 100 PER CENT AND FOR 80 PER CENT ENGINE EFFICIENCY AT THE COUPLING. NO ALLOWANCE FOR REHEAT FACTORS, MOISTURE CORRECTION OR PRESSURE DROP THROUGH REHEATER

Low average use factor during the economic life of a turbine is not always given due weight. For two turbines of the same size, one with high use factor and high fuel cost, the other a stand-by to a hydro-electric plant with low use factor and cheap fuel: In the first case a design for highest economy is needed even at a high price; in the second a cheap unit of indifferent efficiency will serve most economically.

Manufacturers have developed standard sizes of casings which can be given a number of ratings to drive generators of varying capacity, while keeping the annular area of the last row of blades constant, by changing the leaving velocity from the last row and adjusting the dimensions of the high-pressure blading to the quantity of steam flowing at the given rating. A casing can have low rating with low leaving losses or high rating with high leaving losses. Cost of a turbine for a given speed varies with the area of the last row of blades, because modification of the high-pressure blading costs little. Also, at high rating the increased steam flow through the high-pressure blading results in longer blades with less leakage, hence higher efficiency, which partly offsets the increased leaving losses at the high rating; hence a low use factor turbine can be manufactured at low cost per kilowatt by increasing the rated output of a given casing.

In the early days of turbine construction, units were small and an ample blade annulus could be provided at little increased cost, the single annulus of low-pressure blades at 1800 r.p.m. has increased to over 80 sq. ft. At present the annulus of the last blade row varies from about 1.25 to 2.5 sq. ft. per 1000 kw. of turbine rating. The average values of the leaving losses vary from 1.5 to 5 per cent of the total adiabatic heat drop from initial steam conditions to vacuum.

Areas of exhaust openings to the condenser vary from 2.5 to 5 sq. ft. per 1000 kw. of rated capacity, with usual allowance about 4 sq. ft.

When high leaving velocities are used, small exhaust pipes can be furnished and smaller ratios of exhaust area are permissible, if the condenser design provides for proper steam distribution.

Analysis made for a given casing and set of conditions by Francis Hodgkinson shows that for high use factor and high fuel cost, increase in rating over standard will give no material saving in yearly cost of power. As use factor or fuel cost becomes lower, rating can be increased with economy to even as much as 165 per cent of standard.

Turbo-Generators

Water cooled coils for the generator air which is continuously recirculated, have resulted in economic gains from cleaner windings, lower operating temperatures, less fire risk and a one-third reduction in outage.

Generator voltages of 22 kv. are in use in America and a 33-kv. generator is in operation in England. Generators wound for such high voltages cost more than those at 13 kv. but, if the demands of local distribution can be furnished at generator voltage, expense for step-up transformers and low-tension switch gear is eliminated.

Figure 5 shows average efficiencies at rating for

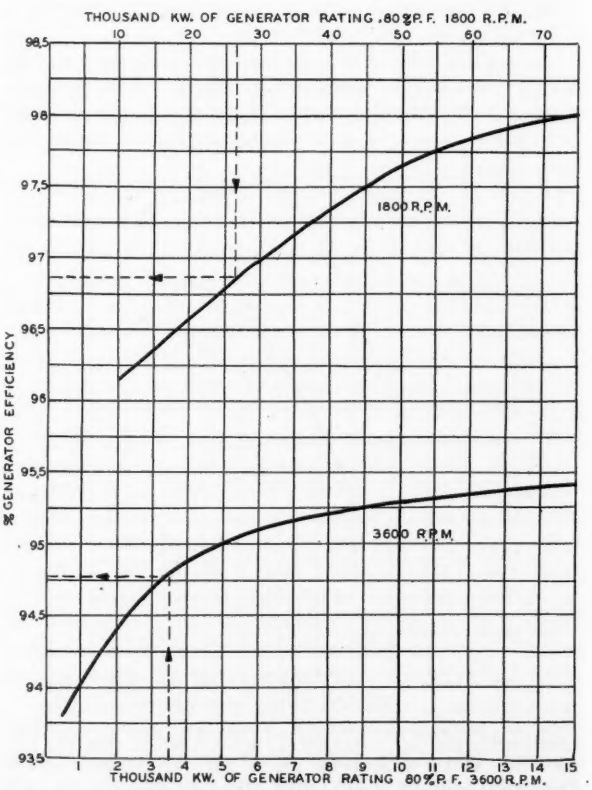

THOUSAND KW. OF GENERATOR RATING .80% P.F. 1800 R.P.M.
1800 R.P.M.
3600 R.P.M.
% GENERATOR EFFICIENCY
THOUSAND KW. OF GENERATOR RATING 80% P.F. 3600 R.P.M.

FIG. 5. AVERAGE AMERICAN TURBO-ALTERNATOR EFFICIENCIES FOR FROM 500 KW. AT 3600 R.P.M. TO 75,000 KW. AT 1800 R.P.M.

generators ranging in size from 500 kw. at 3600 r.p.m. to 75,000 kw. at 1800 r.p.m. with generator voltages from 400 volts for the smaller to 22 kv. for the larger sizes. The maximum deviation of generator efficiency for any size from the values of these curves should not exceed 1 per cent.

Selection of Industrial Turbines

For a given industrial service, the type of small turbine to be selected depends upon the demand it must supply, its efficiency, its use factor and its first cost.

For an industrial plant requiring constant daily supply of large quantities of steam at some pressure above atmospheric, high-pressure boilers can be installed and turbines expand the steam to the needed process pressure, converting a portion of the heat into electrical power. The greater portion of heat in the steam would be exhausted to the process. Electric energy could be generated at a fuel expenditure of about 4500 B.t.u. per kw-hr., representing roughly the consumption of one-third of a pound of coal per kilowatt hour. If this turbine can operate at a reasonably high use factor, the capital charges per kilowatt hour will be low.

Since the amount of steam to be condensed per kilowatt hour is less with higher initial steam pressure, a larger electrical output can be secured from limited available cooling water by utilizing high steam pressure, which favors the installation of boilers for quite high pressure in an industrial plant.

Since pure water should be used as feed for high-pressure boilers operating at high rates of evaporation, if the industrial process is such that no condensate is returned to the boilers, the cost of distillation by evaporators may become prohibitive. In some plants exhaust from a high-pressure turbine goes to reboilers which furnish the process with steam from raw water, while the pure condensate from the reboiler is returned as feedwater.

In general, every industrial plant is a complete problem in itself and each turbine should be designed to meet the demands of that individual plant in the most economical manner. This results in increased first cost on account of the engineering studies and shop changes involved. On the other hand, the fuel savings or increased power output resulting from such careful studies may quickly repay this added cost.

High fuel prices now prevailing and the realization that economies may be secured through the use of high steam pressures with high-pressure or bleeder turbines are changing industrial plant design. Steam temperatures have been kept low because of great variations in superheat, but better fuel burning equipment together with the increasing use of automatic boiler control have done much to ensure steady steam temperatures at the turbine throttle. The advantages of high superheat in small turbines are recognized and steam temperatures will be increased in new industrial power plants.

Viewed as a raw material, petroleum coke is one of the purest forms of industrial carbon available. This product from coking-stills already has a definite market in manufacturers of electrodes and carbon products. Cracking still coke, however, is used primarily as a fuel because of higher volatile content, lower strength and non-uniform quality.

Plant Safety Features Important

Industrial hazards cannot be entirely eliminated but they can be reduced by proper care and attention to details. Many hazards can, of course, be eliminated, but those involving the mentality of the worker can only be reduced.

All kinds of plant operation involves considerable lumber for flooring and staging and twisted, cracked, and knotty pieces should never be used for this service. For staging, it is dangerous because of breaking and shifting, while, for flooring, it causes bulging and warping, a menace to trucking and a serious tripping hazard. Plaster or cement floors should be used where possible.

Trucks are another item of equipment that require careful inspection. Accidents are dangerous to both operator and passerby. They should, of course, be kept well lubricated to reduce man power requirements at a minimum. In addition, truck handlers and push bars should be kept tight in the truck frame; cotter pins and washers should be in place and in good repair to prevent the wheels coming off with all bolts and nuts tight, so as to keep the axle from loosening from the platform.

Scales in almost any plant can be improved. Metal strips on the edges of the platform and pits should be secure and flush with the floor surface. This eliminates the tripping hazard as well as the shock and strain to employes' shoulders and arms, shock to the scale and reduces the number of scale adjustments necessary.

Employes should be warned of the danger of opening car doors too hurriedly. Often shifting takes place during transit and serious accidents occur from packages falling out when the doors are not carefully handled. In this connection, care must be exercised in handling packages with wire or metal clasps or bands, breakage of crockery or glassware and partially hidden or bent nails.

The importance of lighting in accident prevention cannot be over emphasized. Hallways, corner, and intersections require special attention. In the electrical end, the elevator should be included. Cables and wearing parts should be inspected regularly and replaced at the first sign of wear or distress; lubrication should be thorough and adjustments frequent, especially the safety gate and guide rails and shoes.

Elevator operators should be instructed not to handle carelessly or improperly loaded trucks. It is well to have the inside of the elevator covered with a small netting or screen to prevent clothes or bodies of employes from becoming caught on the elevator shaft as the car moves.

Storage areas should be marked with aisles wide enough to permit the passage of loaded trucks. A color line on the floor is a practical method. The aisles should be kept clear and piles not stacked too high nor in a careless manner, which would allow them to fall over when the stack on either side is removed.

Last but not least important is the prevention of infection of slight wounds. This is in a way the most serious, because it is practically impossible to make employes realize the danger of infection and blood-poisoning from small scratches. Drastic measures such as immediate dismissal for neglecting to obtain first aid are sometimes necessary in industries where the danger of infection is worst.

Using Chemicals for Clarifying and Recovering Engine Condensate

OIL CAN BE REMOVED FROM ENGINE CONDENSATE BY MEANS OF CHEMICAL REACTIONS WHICH FORM A GELATINOUS PRECIPITATE. BY A. W. TALBOT AND E. W. PACE

PRESENT DAY TRENDS of modern large power plant design, shunning the use of the reciprocating steam engine for the more efficient steam turbine, are the principal factor in the neglect and disregard of methods of purification of engine condensate so as to make it a desirable feedwater. There are, however, a sufficient number of engines now in use to justify consideration of this much neglected phase of operation. In the following paper, only the chemical reactions involved will be dealt with. The mechanical means employed are separate and apart and largely a matter of personal selection based on the relative merits of the installations offered, consequently they are omitted here.

Oil found in engine condensate has been emulsified to a degree where it is practically in solution and the use of even the most carefully prepared filter medium is inadequate to remove the suspended particles without the assistance of chemicals. The water to be purified must have added to it a chemical to form a coagulant and in this manner remove the oil. For this purpose, a substance such as a soluble salt of aluminum or iron may be employed because of its property to form a gelatinous precipitate. This precipitate in turn entangles the finely divided particles of oil which can then be removed by filtration.

Aluminum sulphate $Al_2(SO_4)_3$ and ferrous sulphate $FeSO_4$ are two such substances suitable for use as coagulants. When aluminum sulphate is dissolved in water it affects a reaction between the aluminum ions and the hydroxyl ions of the water resulting in the precipitation of the aluminum hydroxide as shown by the following equation.

$Al_2(SO_4)_3$	+	$6HOH$	=	$2Al(OH)_3$	+	$3H_2SO_4$
Aluminum Sulphate		Water		Aluminum Hydroxide		Sulphuric Acid

The foregoing reaction is reversible; that is to say, as it proceeds there is an increasing tendency for it to go in the opposite direction so as to re-form the initial substances. This action will continue until an equilibrium is reached. At this point, the hydroxide forming is equal to the hydroxide breaking up. In other words, the concentration of the sulphuric acid will reach a point at which the aluminum hydroxide dissolves as rapidly as it precipitates. If an alkali is present in the water, however, the sulphuric acid will be neutralized as quickly as it forms permitting all of the aluminum hydroxide to be precipitated.

Water which is comparatively high in carbonate hardness carries sufficient soluable bicarbonates to serve this purpose; however, the engine condensate under consideration is practically free from carbonate hardness, consequently an addition of alkali must be made in the form of lime (CaO) or soda ash (Na_2CO_3). For purposes of showing the relative merits of these two alkalies, the reactions which will result are shown below.

$Al_2(SO_4)_3$	+	$6HOH$	+	$6Na_2CO_3$	=	$2Al(OH)_3$	+	$6NaHCO_3$	+	$3Na_2SO_4$
Aluminum Sulphate		Water		Soda Ash		Aluminum Hydroxide		Sodium Bicarbonate		Sodium Sulphate

$Al_2(SO_4)_3$	+	$6HOH$	+	$3CaO$	=	$2Al(OH)_3$	+	$3CaSO_4$	+	$3H_2O$
Aluminum Sulphate		Water		Lime		Aluminum Hydroxide		Calcium Sulphate		Water

Sodium bicarbonate and sodium sulphate resulting from the use of soda ash are soluble and remain so, while on the other hand, the calcium sulphate becomes insoluble when it encounters the high heat in the boiler and will go out of solution to form an extremely hard and detrimental scale.

Aluminum hydroxide is soluble in both acids and alkalies; therefore, in order to obtain the best results, it is necessary to maintain the proper degree of alkalinity in the water. Successful operation, however, is not so dependent upon minimum solubility as upon its physical properties. The principal factor is a good "floc," that is a precipitate of aluminum hydroxide which will form quickly, in comparatively small flakes and at the same time settle rapidly and filter easily. This condition is essential in order to obtain the most effective removal of oil.

Inasmuch as the condensate, after having been freed of oil, is to be utilized as a boiler feed, it is important that the correct proportions of aluminum sulphate and soda ash must be employed. The proper dosages can be readily ascertained if the operator will understand and keep in mind the following points: Aluminum sulphate forms aluminum hydroxide and sulphuric acid in water. Soda ash reacts with the sulphuric acid to form soluble sodium sulphate and soluble sodium bicarbonate. From this, it is apparent that the filtered and purified condensate should give alkaline reactions with both methylorange and phenolphthalein. The latter indicator is necessary to indicate that the soda ash used is slightly in excess of the amount required to neutralize all the sulphuric acid and to prevent any free sulphuric acid or aluminum sulphate from entering the feedwater.

Since the proportion of oil in the water is somewhat variable, it is impossible to have a fixed dosage of chemicals. This must be secured entirely from experimental data and adjusted to meet the requirements of the water being purified. A simple and entirely logical rule to remember is: "Other things being equal, the more oil to be removed, the more coagulant must be employed for its removal."

Essential requirements of a machine to do the work as outlined above may be briefly stated as follows: there must be intimate mixture of chemicals and condensate; the flow through the machine must be sufficiently slow to permit of rapid settling of the floc, and the filter must be of sufficient size to handle continuous runs of 12 to 24 hr. between washings.

Training the Boiler Room Personnel

By R. A. Foresman and Donald J. Mosshart*

FOR BEST OPERATION of underfeed stokers, a few simple rules should be used as a basis for organizing and training the boiler room personnel. They are as follows:

In order to maintain uniform combustion conditions, the rate of coal feed should be proportional to the rate of burning. The operator should be provided with some sort of fuel meter which he can compare and correlate with the steam flow meter. This may be a table of speeds for different stoker motor controller points, an indicating device operated by the stoker engine or stoker turbine governor or some form of tachometer. Any automatic controls of stoker speed should be frequently and carefully checked to assure that they maintain this relation.

A layer of ash should protect the stoker from the heat of the fuel bed. This condition is sometimes hard to maintain with New England Fuels because of their low ash content so that stoker maintenance is sometimes higher in New England plants than elsewhere. The operators should be trained to watch this factor, and it is not improbable that the majority of supervisors could well give the matter study. In this connection, the principal things to watch with clinker grinder stokers is the level of the refuse in the ash pit.

This should be maintained at sufficient height to hold an adequate layer of ash on the lower end of the stoker. With dump grate stokers, care should be exercised that the fire be moved back not too rapidly after dumping the refuse. If the refuse on the lower end of the stoker is suddenly shoved over to the dump grate, the lower end of the stoker and the dump grates themselves, may be unduly exposed to the hot fuel, with resultant burning of parts.

Essentially the underfeed stoker is a machine for producing complete combustion of the fuel in all parts of the furnace. In other words, there should not be a stratum of gas over one section of the stoker containing an excessively high percentage of CO_2 and some CO, and another stratum over another section containing an excessively high percentage of oxygen. Losses from both incomplete combustion and excess air occur under this condition. Also the section of stoker having too little excess air may be overheated.

Distribution of fuel over the grate area should be such that combustion conditions are substantially the same in all parts of the furnace, except over the ash discharge section.

It has long been a custom, accepted as being best practice, to bank boilers when the load drops below a certain point, say 100 per cent of rating, leaving other boilers to operate at higher loads. Some years ago this was probably the best thing to do, because there were no instruments in the boiler room to guide the fireman. The only way to make him fire properly was to throw a heavy load on his boiler so that he had to have a good fire to hold the steam pressure.

*Westinghouse Elec. & Mfg. Co., Philadelphia, Pa.

Basically and practically, this system is wrong. Modern stokers are capable of operation over a range in load of six or seven to one, with substantially the same combustion efficiency at all loads. Instead of banking some boilers and operating others at fairly heavy loads, all boilers should be operated at the same load. The operators should be provided with proper instruments and be held responsible for maintaining efficient combustion at all loads. Such practice will result in material economies, for several reasons:

Due to highly efficient heat absorption by the boiler at light loads, the boiler room efficiency is higher at such loads than at heavy loads; banking losses are eliminated; the stoker parts are cooled by air at all times, instead of being exposed to the heat of a banked fire without a supply of cooling air and all fires are instantly ready to take a sudden increase of load.

Several plants burning Pocahontas coal operate at 50 per cent of boiler rating, 24 hr. per day, for weeks at a time with an efficiency of boiler, superheater and stoker of 83 per cent. At other times these plants carry 250 per cent of rating on the same equipment at an efficiency of 78 per cent.

Difficulties have been experienced from the formation of slag masses on the lower tubes of the boiler. Much theorizing about the causes and reasons for this slag formation has been indulged in by engineers. Various boiler manufacturers have produced slag screens which, in most cases, have effected marked improvements. Nevertheless the problem remains even though it be in a modified form. Slagging of tubes is, of course, due to the air current lifting ash particles out of the fuel bed and depositing these particles on the tubes of the boiler.

Remembering again the laws of physics, we would expect the slag formation to vary approximately as the square of the velocity of air through the fuel bed, or, in other words, as the square of the combustion rate. Therefore, the only control that the stoker can exercise over slagging of the tubes is to operate with a maximum activity of fuel bed so that the air velocities through the fuel bed are as low as possible.

Semi-bituminous coals are bad slaggers because the slowness of these coals to ignite reduces the active burning area of the stoker and increases air velocities through the fuel bed; the ash in the majority of these

All boilers should be equipped with means for removing the slag from the lower tubes while the boiler is in operation at light loads or is banked. By far the most effective means of slag removal is to lance the tubes through doors located at the top of the furnace just below the boiler tubes. Such doors are readily installed with either brick walls or water walls. A walkway should be provided so that men can easily reach all parts of the lower tubes with a lance. Convenient connections should be provided at both sides of the boiler so that two or more men can work simultaneously and keep the lancing period as short as possible.

JOINT USE of Diesel and Steam Engines to BALANCE HEAT and POWER*

By Edgar J. Kates†

TO BALANCE HEAT and power means to utilize most economically space-heating and process steam in providing byproduct power. There are many plants where this desirable balance has never been achieved. There are still others where the balance that once existed has been destroyed by the march of progress. Heat demands have changed but little while power requirements have grown rapidly.

Diesel Power a Factor in Heat Balance

In endeavoring to reduce the cost of the prime steam power, engineers have generally limited themselves to modifications in the steam plant itself and have disregarded the possible use of Diesel engines for supplementing ordinary steam equipment and improving the overall economy. The Diesel engine claims attention when and if its fuel cost per kilowatt-hour is less than that of a steam power plant whose exhaust heat is being wasted. Whether or not the addition of Diesel power is a better solution than a major alteration in the steam power plant itself, depends upon so many variably conflicting factors that it can be decided only after careful engineering analysis of each individual case.

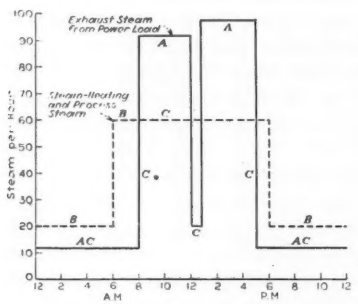


FIG. 1. HEAT-USE FACTORS IN AN ALL-STEAM POWER PLANT

Fond as the engineer is of the B.t.u., it must be recognized at the outset of any study involving the joint use of Diesel and steam engines, that a thermal analysis alone will not have any practical meaning, because there is a great difference in the monetary value of a B.t.u. in the form of boiler oil and a B.t.u. in the form of Diesel fuel, the latter being 25 to 75 per cent more expensive. A study of this sort must, therefore, be primarily economic with heat values always converted into dollar values.

Utilization of Exhaust Steam

Economy of joint Diesel and steam power is closely related to the ratios between the amount of steam doubly used for heat and power, and the amounts used for either heat or power alone. These heat-use factors are illustrated by Fig. 1, which is an assumed chart of steam consumption for power and for heat in an all-steam power plant during a 24-hr. period.

Here: "A" is the exhaust steam output of the steam power plant, which varies with the power load; "B" is the low-pressure steam consumed in space-heating and process, i.e. the "heat load" and "C" is the engine exhaust steam utilized, i.e. the portion of "A" that is also used to supply the heat load.

Then: C ÷ A = "Exhaust-Use Factor." Shows proportion of steam power that is byproduct. B ÷ A = Ratio of heat load to exhaust output. C ÷ B = Proportion of heat load supplied by exhaust. Remainder is heat to be supplied by reducing valve. B — C = Heat supplied by reducing valve. A — C = Unused exhaust steam, corresponding to "prime" steam power.

Although it is the heat load "B" which makes possible the double use of steam for heat and power, the thermal analysis must start at the other end, i.e. the power load, inasmuch as an installed steam power plant

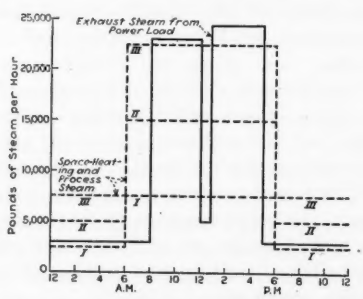


FIG. 2. ASSUMED STEAM CONSUMPTION FOR 24-HR. PERIOD

*Abstract of paper presented at the national meeting of the Oil and Gas Power Division of the A.S.M.E. held at State College, Pa., June 12-14, 1930.

†Consulting Engineer, New York City.

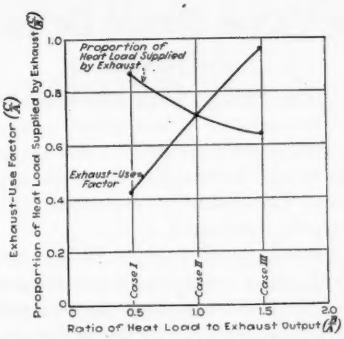

Proportion of Heat Load Supplied by Exhaust
Exhaust-Use Factor
Case I
Case II
Case III
Exhaust-Use Factor (C/A)
Proportion of Heat Load Supplied by Exhaust (C/B)
Ratio of Heat Load to Exhaust Output (B/A)

FIG. 3. HEAT-USE FACTORS COMPUTED FROM GRAPHS

has a definite power capacity and the real question is how much of the exhaust output of that power capacity can be utilized for heating. In other words, it is essential that the exhaust-use factor, C ÷ A, should be large to increase the proportion of byproduct power, whereas it matters little what proportion of the heat load is supplied by the exhaust, i.e. C ÷ B, since the remaining heat load must be supplied by the boilers in any case.

The exhaust-use factor is an extremely important consideration in studies of heat and power balance and it must be correctly derived. Daily, monthly, or annual averages of heat and power consumption cannot be used directly in studies of private power plants unless the exhaust-use factors at all times are definitely known. This is made clear in Fig. 2, showing the assumed steam consumption for power and heat over a 24-hr. period in an all-steam power plant having the same power curve for each day of the year but variable space-heating and process steam requirements as follows: I—Heating steam per day = 50 per cent of power exhaust steam per day. II—Heating steam per day = 100 per cent of power-exhaust steam per day. III—Heating steam per day = 150 per cent of power exhaust steam per day. Table I and Fig. 3 show the heat-use factors computed from these graphs.

Effect of Diesel Power on Overall Thermal Economy

Addition of a Diesel engine to a steam power plant may improve the overall thermal economy in two ways, (a) by increasing the exhaust-use factor of the steam plant, (b) by replacing expensive "prime" steam power with less expensive Diesel power. This is illustrated by

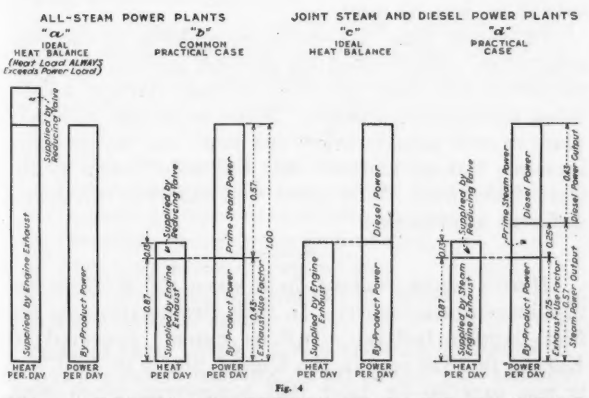


FIG. 4. EFFECT OF ADDITION OF DIESEL TO STEAM POWER

Fig. 4. "a" and "b" refer to all-steam-power plants. "a" shows an ideal case based on the assumption that the heat load always exceeds the power load, and that the exhaust steam is therefore fully utilized, (exhaust-use factor 100 per cent). In this case all of the required power is produced as a byproduct.

Whether Diesel exhaust heat recovery is justified depends upon the cost of recovering it, (including investment charges) and upon the cost of the heat it displaces. In all-Diesel plants with small heat-load, the exhaust heat may be highly valuable because it greatly simplifies the problem of heat supply. On the other hand, in combination steam and Diesel power plants such as are now being discussed, the availability of low-cost exhaust steam at all times minimizes the value of

TABLE I. HEAT-USE FACTORS CORRESPONDING TO LOAD CURVES OF FIG. 2

	Symbol	Case I	Case II	Case III
Ratio of heat load to exhaust output	B ÷ A	0.50	1.00	1.50
Exhaust-use factor	C ÷ A	0.43	0.71	0.96
Proportion of heat load supplied by exhaust	C ÷ B	0.87	0.71	0.64
Unused exhaust, 1000 lb. per 24 hr.	A — C	136	70	10

TABLE II. ESTIMATED INITIAL COST OF 750-HP. DIESEL-ENGINE INSTALLATION TO DRIVE 500-KW. GENERATOR OF STEAM UNIT

Engine	$37,500
Foundation (additional)	2000
Fuel tank	1000
Freight and carting	1700
Piping	1000
Pumps, air compressor, oil reclaimer, flexible coupling, etc.	1500
Building space, additional	1500
Contingencies	1300
Engineering	2500
	$50,000 (= $100 per kw.)

TABLE III. EFFECT OF DIESEL POWER UPON HEAT-USE FACTORS IN JOINT POWER PLANTS

	All-steam Power		Case IV		Case V	
Total power load	845		845		845	
Steam power capacity	845		845		600	
Diesel power capacity	0		414		414	
Season	Winter	Summer	Winter	Summer	Winter	Summer
Heat load, B	III	I	III	I	III	I
Ratio of heat load to exhaust output, B ÷ A	1.50	0.50	1.50	0.87	1.90	0.87
Exhaust-use factor, C ÷ A	0.96	0.43	0.96	0.75	1.00	0.75
Proportion of heat load supplied by exhaust, C ÷ B	0.64	0.87	0.64	0.87	0.53	0.87
Reduction in exhaust output by substituting Diesel power, 1000 lb. per 24 hr, D	0	0	0	102	50.8	102
Proportion of daily power output generated by Diesel, D ÷ (A + D)	0	0	0	0.43	0.21	0.43
Unused exhaust steam, 1000 lb. per 23 hr., A — C	10	136	10	34	0	34

TABLE IV. RESULTS OF TWO STUDIES FOR HEAT AND POWER SUPPLY

Type of service	Large Loft Building			Large Department Store		
Annual consumption of low-pressure steam	33,000,000 lb. per year			90,100,000 lb. per year		
Annual consumption of electricity	4,200,000 kw-hr. per year			7,576,000 kw-hr. per year		
Maximum demand for low-pressure steam	25,000 lb. per hour			47,500 lb. per hour		
Maximum demand for electricity	1500 kw.			2419 kw.		
Type of plant considered	Purchased power	All-steam power	Joint steam & Diesel	Purchase power	All-steam power	Joint steam & Diesel
Steam power plant capacity	0	1700 kw.	1000 kw.	0	3000 kw.	1200 kw.
Diesel power plant capacity	0	0	700 kw.	0	0	1800 kw.
Annual overall cost including fixed charges	$127,500	$113,260	$105,460	$143,650	$123,600	$98,190
(Items common to all types of plants omitted)						

the Diesel-exhaust heat. In any case, the heat recoverable from Diesel engines is too small in comparison with the heat demands in the sort of problems here under consideration, to have any important influence upon the economic balance.

Major cost variables in this analysis are fuel costs and fixed charges; maintenance, lubrication, supplies, supplies, ash-removal, make-up water, and feed-water treatment. It is not implied that attendance is a minor item of power cost but that the difference in attendance cost between steam and Diesel units is small. Furthermore, the various minor cost variables offset each other to such an extent that they do not appreciably affect the results of a preliminary study and may therefore be ignored here.

Combination of steam and Diesel power will effect a considerable saving in initial cost by reducing the installed generator capacity, the wiring from generator to switchboard and the switchboard itself. It will also reduce foundation size and cost inasmuch as the Diesel engine will have the benefit of the steam engine foundation. Furthermore, there will be a considerable saving in space occupied. If the steam engine is of the vertical, multicylinder type the space saving will be still greater; in this case the common generator might have its own shaft and bearings, with flexible couplings on both sides. Table 2 is an estimate of the initial cost of a 750-hp. Diesel engine to drive a 500-kw. generator mounted on a steam-engine shaft. It will be noted that the additional cost of the Diesel end is $100 per kw.

1. Diesel engines can be effectively used in conjunction with certain types of steam power plants to produce power and heat at low overall cost. Their utility consists in enabling the steam plant to produce the optimum quantity of byproduct power from space-heating and process steam, while the Diesel units generate the remaining power at lower cost than a steam plant would.

2. In such joint steam and Diesel power plants the total plant capacity need not exceed that of a corresponding all-steam power plant. Despite some loss in thermal economy, the decreased investment results in lower overall costs.

3. In any study of the use of power steam for heating purposes, the exhaust use factor must be determined with the utmost care. Detailed analysis of power and heat requirements at all hours of the day, and at all times of the year must be made, otherwise the amount of exhaust steam utilized may be greatly overestimated, and erroneous conclusions reached.

4. The actual design of a joint steam and Diesel power plant is a piece of real engineering, and deserves the application of competent engineering skill and experience.

HOLES IN CONCRETE floors can easily be repaired over night. The hole or depression should be chipped out to solid material and the hole filled with a mixture of half sharp sand and half cement trowled and packed firmly in and around the edges. About a half-inch layer of flake calcium chloride spread on top will give it the so-called calcium dry. This insures a good bond between the new mixture and old floor and sets quickly. It can be trucked over in from 6 to 8 hr.

Safety Valves Should Be Carefully Adjusted

SAFETY VALVE leakage while not serious is one of the troublesome features of power plant operation. With improved plant operation, boilers do not pop as often as they used to and the improved valves available today have cut down the difficulty somewhat although it has not been entirely eliminated.

Actual loss of steam is negligible, especially when compared with other leaks which are commonly present, but it is unsightly and a sign of sloppy operation. Left alone, the seat and valve will be badly cut. If poorly adjusted, the valve may not seat or it may warm at a pressure below the blowdown point. This is not leakage as commonly thought of but this condition will lead to leakage if not corrected.

A common source of trouble is foreign matter, often a piece of scale caught under the valve at blowdown. Sometimes the particle remains and holds the valve open; more often it only causes a nick which later develops a leak. It should be remembered that, because of the accurate adjustments necessary, the seat is very narrow, around $\frac{1}{16}$ in. on even large valves, and a slight indentation on this narrow ring causes a leak which rapidly eats away the valve and seat under full boiler pressure.

With the usual method of making seats, the disc has a slightly different angle from the seat and both are so shaped that the circle of contact is as small as possible. This narrow seat gives a minimum area of contact and a high loading per unit of area.

Distortion of the seat due to unequal expansion or more often piping strains from unsupported outlet piping is a common cause. For this reason, it is well to have any piping entirely free from the safety valve proper. It is because of distortion that a careful engineer grinds in his valve after it is in position.

Poorly fitted guides or scale sometimes forces the disc out of position and binding of the spindle against the spring or adjusting bolt will do the same thing. Sometimes leakage will occur between seat ring and body, particularly on a cold valve. It should always be remembered that a safety valve will leak sometimes when cold, but will stop when properly heated up. Sometimes a faulty casting is to blame but with the high grade valves today any engineer is more than reasonably safe in assuming that the valve will perform properly if he does his part.

Of course, some leakage is unavoidable, as the popping point is approached the pressure holding the valve in place is very small and steam leakage starts at a little below the popping pressure. Noiseless leakage may take place several pounds below the pop. As the pressure increases leakage increases and a hissing known as the warn takes place. This varies with different valves and different adjustments.

HERO'S STEAM TURBINE, built about 200 B. C., is the first known prime mover. In 1629, Branca invented the first impulse turbine. Turbine patents appeared in Europe in 1820 and in the United States in 1831 but it was over 50 yr. later that commercial types were developed.

Calculating Air Necessary for Combustion

Gas Volumes Arrived at by Calculation Usually 20 to 30 Per Cent Below Pitot Tube Tests. By J. R. Darnell*

FORMULAS for determining excess air should be used with caution. Unless the correctness of the flue gas analysis has been previously checked, there is no assurance that a true value for excess air will result. Errors resulting from this are frequently reflected in disputes over induced draft fan performance. It is not unusual when a new boiler is started up and before careful final adjustments are made to the various pieces of combustion equipment, to find that the maximum desired boiler capacity cannot be attained. Since the induced draft fan is at the end of the system all errors are passed along to it.

Frequently attempts are made to check fan performance by weighing the fuel and analyzing the flue gas. A representative ultimate analysis of the fuel and the temperature of the gas entering the fan must also be obtained. Consider the possibility of error in all these factors. In the problem to be discussed later, the error in flue gas analysis would account for approximately 5 per cent error in gas volume being handled by the fan. This alone would not be serious but since any of the other steps necessary to calculate the flue gas volume might easily involve an error of 5 to 10 per cent also it can be readily seen that if all errors are in one direction there might be a total error of 20 to 40 per cent.

As a matter of fact, careful fan tests often show that the indirect method of determining the flue gas volume actually is in error in these proportions, giving volumes lower than by tests made according to the Fan Manufacturers Test Code.

In all cases of which we have record the volumes resulting from calculation are 20 to 30 per cent lower than those resulting from pitot tube tests. In one case, pitot tube measurements gave 180,000 c.f.m. while calculations based on gas analysis gave 145,000 c.f.m., a difference of 19.4 per cent. In another case the pitot tube showed 126,250 c.f.m. but the other method indicated only 90,000 c.f.m., which is 28.7 per cent lower. A third case showed 53,000 instead of 42,000 c.f.m., or an error of 20.8 per cent.

It seems strange that power plant engineers should seriously consider checking fan performance with methods so fraught with possibilities of inaccuracy. Consider the following items all possible sources of errors:

1. Obtaining representative flue gas sample.
2. Obtaining accurate flue gas analysis.
3. Obtaining representative average temperature.
4. Obtaining representative fuel sample.
5. Obtaining accurate analysis of fuel.
6. Obtaining accurate fuel weight.
7. Obtaining accurate analysis of refuse.
8. Calculation of data.

Some of these possible errors are well illustrated in the April 1 issue, page 388, in the article by Professor Martin under the above title, in which he describes a method of determining excess air from flue gas analysis. This is substantially correct except for the fact that there has been an error in obtaining the values given in the flue gas analysis.

Professor Martin based his calculations on flue gas analysis given as follows:

CO_2	11.64 per cent
O_2	7.68 per cent
CO	0.17 per cent

This, apparently was obtained in the burning of wood of the following analysis, dry basis:

Carbon	50.36 per cent
Hydrogen	5.92 per cent
Oxygen	43.39 per cent
Nitrogen	0.05 per cent
Ash	0.28 per cent

It was stated that the amount of carbon in the ash-pit refuse was negligible and therefore all the carbon in the fuel was assumed as being in the flue gas. With such an analysis we can calculate the maximum theoretical CO_2 which may be obtained with no excess air either by Formula I or II.

$$M = \frac{20.9}{1.0 + \frac{2.38\,(H - 0/8)}{C + 0.37\,S}} \qquad \text{I}$$

$$M = \frac{8.86}{0.424 + \frac{H - 0/8}{C + 0.37\,S}} \qquad \text{II}$$

Where M = maximum CO_2 and H, O, C and S are the percentages by ultimate analysis of hydrogen, oxygen, carbon and sulphur respectively.

Substituting the values of the ultimate analysis in the above formulas we obtain 20.4 per cent as the maximum CO_2.

The amount of excess air may be next determined:

$$E = \frac{[M - (K + k)]\ .79}{K + k\,(100 - M)} \qquad \text{III}$$

Where E = per cent excess air
M = maximum CO_2
K = actual CO_2
k = actual CO

Substituting in Formula III we obtain 72 per cent excess air. However, according to Professor Martin's calculations the excess air is only 62.2 per cent. As previously stated this is due to an error in obtaining the correct flue gas analysis. Assuming that the values for CO_2 and CO are correct, the oxygen in the flue gas should be 8.9 per cent instead of 7.68. This may be determined as follows:

$$O_2 = 21 + 0.4\,k - \left(\frac{21\,(K + k)}{M}\right) \qquad \text{IV}$$

*Asst. Mgr., Economizer and Mech. Draft Dept., B. F. Sturtevant Co., Boston, Mass.

Maximum CO_2 may be checked by flue gas analysis by the following formula:

$$M = \frac{21\,(K + k)}{(21 - O_2) + 0.4\,k} \qquad V$$

Acording to this formula, if we substitute the values for flue gas analysis as given by Professor Martin, we obtain 18.6 per cent maximum CO_2. This does not check with the value of 20.4 as given by Formulas I and II.

Since we have found by Formula IV that the amount of oxygen in the flue gas should be 8.9 per cent, if we use this value in equation (5) we obtain 20.4 per cent maximum CO_2 which checks equations I and II.

Data from which were derived all of the foregoing formulas, except I, appeared in the April, 1926 issue of Mechanical Engineering in an article by A. A. Bato. An abstract of this article was published in Power Plant Engineering August 1, 1926. This paper entitled "Flue Gas Computations" is one of the best discussions of the subject the writer has ever read. It gives complete derivations of all of these formulas.

There are two questionable points about the flue gas analysis given by Professor Martin. The percentage of oxygen as given is too low and also it is doubtful if there is any CO present with the relatively large amount of excess air shown.

One of the most common errors in flue gas analysis is failure of removing completely all of the oxygen. Some of this oxygen is then reported as CO since the cuprous chloride solution will readily absorb oxygen. In this case we might well assume that the 0.17 per cent CO should have been reported as oxygen with approximately an additional 1 c.c. of oxygen unaccounted for.

It should be noted also that rarely, if ever, is it possible to report flue gas analysis any closer than to 1/10 of 1 c.c. especially if the ordinary type water Orsat apparatus is used.

If we substitute the value of 8.9 per cent O_2 instead of 7.68 per cent as shown by Professor Martin's calculations, we obtain 10.32 lb. air supplied per lb. dry fuel burned. Since 6 lb. air per lb. dry fuel are theoretically required, the amount of excess air may be calculated as folows:

$$\frac{10.32 - 6.0}{6.0} = 72.0 \text{ per cent excess air.}$$

This checks with the value obtained by Formula III.

In general, where combustion is complete or practically so, (0.1 to 0.2 per cent CO may be disregarded) the sum of the CO_2 and O_2 should slightly exceed the value for maximum theoretical CO_2. Among engineers accustomed to making flue gas analyses the matter of observing and checking the "totals" is an important one. After long practise it is done almost sub-consciously. For example, with most bituminous coals, the maximum theoretical CO_2 with no excess air varies between 18.4 and 18.7 per cent. If an analysis is made which gives CO_2 as 15.0 per cent the oxygen will be approximately 4 per cent. If the CO_2 is 14.0 per cent the oxygen should be approximately 5 per cent. If an oxygen content of only 3 to 4 per cent was reported the experienced flue gas analyst would detect the error at the first inspection.

The following table gives approximate values in per cent of maximum CO_2 for representative fuels of various classes:

1.	By-product coke oven gas	9.4
2.	Natural gas	11.6
3.	Oil refinery gas	13.3
4.	Fuel oil	15.4
5.	Pittsburg bituminous	18.4
6.	Mid-western bituminous	18.6
7.	Eastern bituminous	18.7
8.	Lignite bituminous	20.1
9.	Wood (hogged or mill refuse, dry)	20.4
10.	Blast-furnace gas,* (dry)	25.0

*Blast furnace gas before combustion may contain 12 to 13 per cent CO_2.

A formula even simpler than the method described by Professor Martin may be used to determine the amount of air theoretically required for combustion.

Lb. of air per lb. fuel = 11.52 C + 34.6 (H-O/8) + 4.32 S VI

This equation, together with Formula III for determining the percentage of excess air, may be used to calculate the amount of air supplied per pound of fuel for any given CO_2 value.

SULPHURIC ACID is the cornerstone of the chemical industry, about 7,000,000 t. of 50 deg. acid being produced in 1928. Some of this acid is made as a by-product of industry; for instance, copper smelting by reclaiming the SO_2 in the stack gases. The rest is made from burning either brimstone or pyrites by either the contact or chamber process.

Various strengths of acid are marketed commercially up to about 60 deg. Bé. which is known as oil of vitriol. This is 93.2 per cent H_2SO_4 and has a specific gravity of 1.835. Much of it is used in weaker solutions as electrolyte but most of it is used for making other chemicals.

For instance, muriatic or hydrochloric acid is made from common salt, sodium chloride, and sulphuric acid. Hydrochloric acid gas liberated by the reaction is absorbed in water to form the commercial product. A by-product of this is salt cake used in the paper industry in making Kraft paper.

Muriatic acid is used in all industries, principally dyeing, sugar, paper and metals. It is marketed in strengths up to 22 deg. Bé., at which it is about 35.2 per cent HCL with a specific gravity of about 1.179.

Nitric acid is obtained from sodium nitrate and sulphuric acid. Three different grades are marketed: aqua fortis with some oxides and chlorides, nitric acid with some chlorides and chlorine-free acid with neither chlorine or oxides. It is widely used in the explosives, etching, photo engraving, chemical and dyestuff industries and is marketed in grades up to 42 Bé., which is about 67.2 per cent HNO_3 with a specific gravity of 1.408. A mixture of sulphuric and nitric acid known to the trade as mixed acid is used in nitrating.

Bauxite treated with sulphuric acid gives sulphate of alumina, known to the trade as alum and extremely important in water treating and paper-making. Commercially it runs about 17 per cent, although a 22 per cent grade is available and it is said that the concentrated product has been used successfully without soda ash in places where the latter was formerly necessary with the regular grade of alum.

American Coal Firing Practice*

RESULTS OF A SYMPOSIUM CONTRIBUTED TO BY ENGINEERS PROMINENT IN THE COMBUSTION FIELD. BY H. W. BROOKS

TO GET a comprehensive and authoritative cross-section of American practice, review of the present conditions was asked from E. G. Bailey, president of The Fuller-Lehigh Co.; W. L. Martwick, manager, Pulverizer and Furnace Division, The Foster-Wheeler Co.; F. H. Daniels, president, The Riley Stoker Corp.; H. D. Savage, president, Combustion Engineering Corp.; T. H. Banfield, president, Iron Fireman Mfg. Co. From their statements conclusions have been summarized and some statements quoted, in order to give a picture of present conditions and progress.

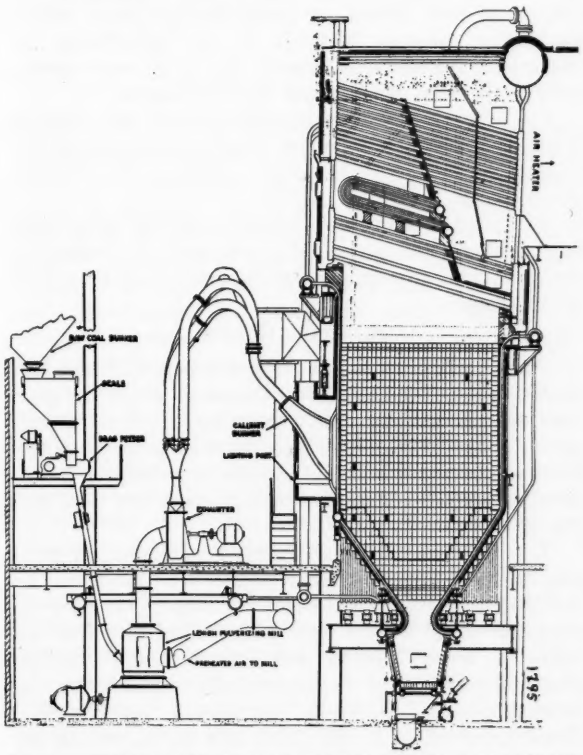


FIG. 1. DIRECT-FIRED PULVERIZED COAL UNIT, 280,000 LB. STEAM AN HOUR, 450 LB., 700 DEG.

YEARLY COAL CONSUMPTION

Estimate of coal burned under American boilers classifies about as follows: Hand-fired, 275,000,000 t.; underfeed stokers, 100,000,000 t.; chain grates, 40,000,000 t.; pulverized coal, 25,000,000 t.; total, 430,000,000 t. United States government statistics show that stokers still serve about 60 per cent of water-tube boilers manufactured, so that engineers evidently appreciate that each method has its field of use and it is well to try to establish lines of demarcation of these fields. A helpful trend is the merging of firing equipment, water-cooled furnace and boiler manufacture into single corporations giving undivided responsibility for the results from steam-generating units.

STEAM GENERATING INTENSIFIED

Present-day large units, 800,000 lb. of steam per hour, high pressures, now up to 1800 lb. and increased heat absorption rates, up to 25,000 B.t.u. per square foot of heating surface per hour, with little decrease in efficiency, have reduced investment costs. Heat generated per developed horsepower of 33,479 B.t.u. has been reduced from averages of 46,000 for central stations and 56,000 for industrial plants to 42,000 for central stations and 47,800 for industrial plants over a period of 10 yr., best results now being, 38,000 for central stations and about the same for industrial plants. The gains have been 10 per cent and 25 per cent respectively.

PULVERIZED FUEL FOR HIGH CAPACITY

From the discussion by E. G. Bailey, the trend toward even larger units seems likely to continue, with demand for increased furnace capacity. Pulverized fuel can take advantage of all three furnace dimensions in meeting this demand and has sufficient flexibility to permit coal of widely varying grades to be burned in a single installation. Air heater surface for reclaiming flue gas heat has been found "appreciably less expensive than boiler or economizer heating surface." Highly preheated air requires, however, water-cooled furnace construction.

Unit pulverized coal installation, Fig. 1, have low first cost, simple design, easy operation and reliability and do away with difficulties encountered when pulverized coal is stored, such as condensation, arching and channelling in the bunker, deterioration of bunkers and gates, the dust problem when separating mill air from coal.

Recent developments in pulverizing mills make for smoother operation, greater capacity and lower power consumption.

In furnaces, high availability and efficiency, smokelessness over a wide range of capacity, low maintenance cost and ease of ash removal are essentials. Slag tap furnaces, the molten ash and slag accumulating on a floor from which it is tapped in liquid form are coming into wide use. These furnaces get a larger percentage of the ash than those which collect in dry form also take less head room, reduce cost of ash handling and practically eliminate air leakage from the ashpit.

PULVERIZED COAL FOR INDUSTRIAL PLANTS

As advantages of pulverized fuel for industrial plants, W. L. Martwick enumerates, ease of burning, simplicity of control, high thermal efficiency, low banked loss, ability to handle a wide range of fuels.

*Abstracted from a paper before the World Power Conference, Berlin, June, 1930.

As advantages of using the storage system he gives, use of smaller grinding mills and operation at economical load on off peak periods, lower power requirements. He states, however, that the trend is toward unit systems, using heated drying air in the mill and passing it directly to the furnace.

Three types of mills are listed: The beater, impact or hammer type, running at 1200 to 2000 r.p.m., in which grinding is by swing or rigid hammers, the grinding being by impact against beaters or casing and by attrition; ball or roller type which crushes between balls or rollers and a ring, running at 100 to 300 r.p.m. and utilizing weight or centrifugal force to do the crushing; slow-speed ball type where pulverizing is by the impact of loose rolling balls. The hammer type is simple, usually has a built-in fan which supplies the air current for removal of the fired coal and is easily repaired. It is advised for small installations where coal is not abrasive in character. The slow speed ball mill is the most successful for grinding the hardest coals and coke, but loses somewhat in capacity with wet fuel, though not so much as the higher-speed ball or roller mill.

For industrial furnaces, refractory lining, preferably air-cooled, involves least maintenance and carbon loss and can be used where heat releases are not over 18,000 B.t.u. per cubic foot per hour, so as to give long flame travel. Such travel may be secured by firing downwards from a point near the top of the furnace, by horizontal burners located low in the front wall or by firing from four sides tangential to a circle so as to give a helical flame.

Ash is generally removed solid from the bottom of the furnace.

For vertical downward firing and for horizontal firing in slagging furnaces, the non-whirling burner has been found successful, one to five pounds of air per pound of coal being fed through the burner and for vertical burners the balance through air ports in the front wall; for horizontal burners, the secondary air is admitted under pressure around the burner.

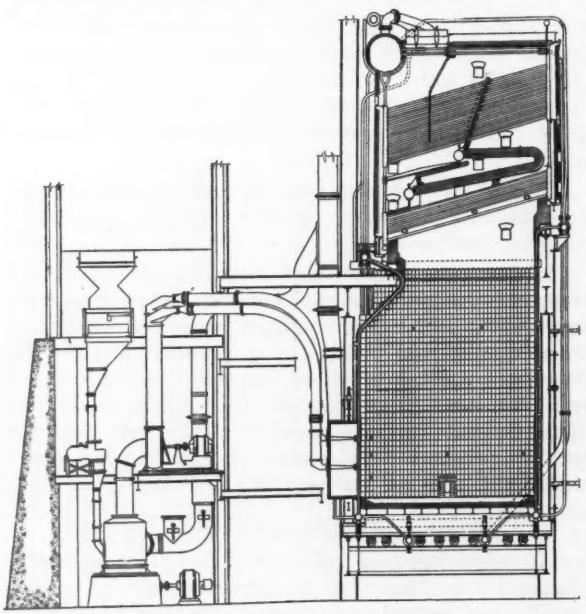


FIG. 2. SLAG-TAP FURNACE WITH WATER-COOLED WALLS

For a rotating flame, either all air comes in with the fuel or secondary air is admitted in jets near the point of fuel entrance.

Underfeed Stokers

In regard to underfeed stokers, Mr. Daniels gives their use as primarily for burning high-grade, bituminous coal, having low ash of high fusing temperature. Satisfactory installations have, however, been made to handle midwestern coals high in moisture and in ash of low fusing point. Anthracite, coke breeze and lignite are not well adapted for underfeed stokers.

To serve large units operated at high ratings, multiple retort stokers are in use, the full width of the boiler and over 20 ft. long, necessitating changes from previous design. Projected areas of over 700 sq. ft. are frequent in both single and double ended stokers. Increase in heat release per square foot of grate area,—combustion rates of 70 to 75 lb. per hour being not uncommon, is possible because of the use of water-cooled walls to prevent clinker and slag formation.

Use of preheated air up to 350 deg. F. has resulted in improvement of combustion; higher temperatures are possible but not with the same certainty of increased over-all plant economy.

For lengths over 15 ft., clinker grinders with large, deep clinker pits are generally used and zone control of air is provided to regulate combustion on different parts of the stoker.

Traveling Grates

Traveling grates and chain grates were differentiated by Mr. Savage, one as having chains on which the grate bars are carried, the other carrying the fuel directly on the chain links. Their use has been largely for free burning coals with high ash content, especially in middle western states. Strongly coking coals are not well suited to these grates.

Low settings and small furnace volumes have given way to high furnaces, front arches set well above the fuel bed and controlled zoned air supply, draft being regulated according to the thickness of the fuel bed above the zone. Lignites, sub-bituminous coals, anthracite and coke breeze are successfully handled, at combustion rates up to 40 lb. per square foot per hour. Grate areas of 24 by 22 ft. or 528 sq. ft. are in use. For some fuels, a rear arch, extending well forward over the grate has increased capacity and, where a variety of coal is to be burned, both front and rear arches have improved performance.

Summary

Reviewing these discussions, Mr. Brooks concludes that unit pulverizers, fine grinding, water-cooled walls, preheated air, slagging type furnaces and, for bituminous coal, horizontal turbulent burners are growing in popularity in pulverized fuel practice. Trends are toward lower equipment cost, better separation of ash from flue gases, less costly and more reliable automatic control and portable truck mounting of pulverizers.

For stokers, notable advances are increase in size and combustion rate, preheating and zone control of air, coördination of all parts of the steam-generating unit, use of water-cooled walls and arches, use of clinker grinders and pits, also of rear and front mixing and combustion arches.

Automatic Control of HYDROELECTRIC STATIONS *by the* All Relay System

A Discussion of the New All Relay System of Automatic Hydroelectric Station Control With Particular Reference to Its Application at the Doris Lake Plant Near Sargent, Nebraska.

Part I

by E. H. Stivender

DESPITE SOME DISCUSSION that automatic hydroelectric plants will be a thing of the past in a few years many are of the opinion that automatic control of isolated stations will become increasingly indispensable in the future. The installation of small plants in isolated sections of the power system is highly desirable for continuity of service and owing to the great development of automatic control greater reliability is obtained from small automatic hydro plants than from manually operated plants since operators, because of increasing expense, are not kept on duty 24 hr. a day. Although their installation has been mostly limited to units of 1000 kw. and less the successful operation of units of 20,000 kw. and more by automatic control indicates that in the future large stations may be operated continuously with only the occasional visit of an inspector.

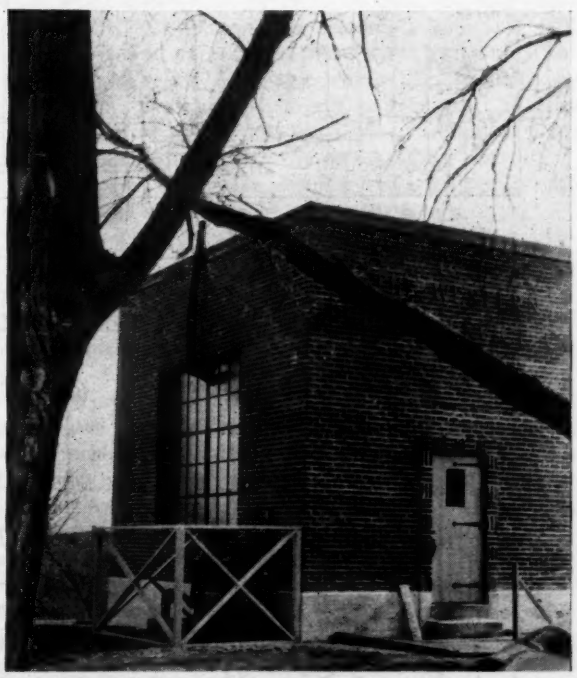
Automatic hydroelectric plants are included in two classes, namely "full automatic" and "semi-automatic." Full automatic plants are those which are started, synchronized with the line, and loaded without requiring the presence of an operator, while semi-automatic plants require manual starting and synchronizing. The operation of these plants may depend on a number of devices, such as push-buttons, time switches, float switches, overload relays, under voltage relays and supervisory control; these control devices are practically the same for all stations but the methods of starting, stopping, synchronizing and load pickup differ greatly in many cases.

At Doris Lake, near Sargent, Nebraska, a 200-kw. generator with water wheel and complete automatic switching equipment was furnished and installed by Allis-Chambers Mfg. Co. for Stone & Webster Engineering Corp. The unit consists of a 300-hp. Nagler four-blade propeller type water wheel driving a 200-kw., 164-r.p.m., 2300-x. vertical generator. The automatic switching equipment is the new Allis-Chalmers "All-Relay" type. The switchboard consists of three panels and a regulator panel which besides allowing for instruments and relays for automatic control of the present installation, with one oil circuit breaker, also have room provided for the future installation of automatic control equipment for two additional circuit breakers. The governor and brakes are the Woodward oil pressure type with motor-driven fly-balls for the governor. All equipment with the main unit is installed in a 15 by 22-ft. brick building.

This article refers to a particular installation but the basic operating principles of the "All-Relay" system is the same for all plants.

Although the "All-Relay" system of automatic hydro station control is a recent development its installation and successful operation in a number of plants has demonstrated it to be a fast and reliable method.

Perhaps the simplest method of illustrating automatic switching equipment is by means of schematic diagrams. Figures 2, 3, and 4 show schematic diagrams of the automatic equipment installed at the Doris Lake plant. Figure 1 is for reference explaining the symbols used in Figs. 2, 3, and 4.



FRONT VIEW OF POWER HOUSE SHOWING TRANSFORMERS FOR ELECTRICALLY HEATED TRACK RACKS

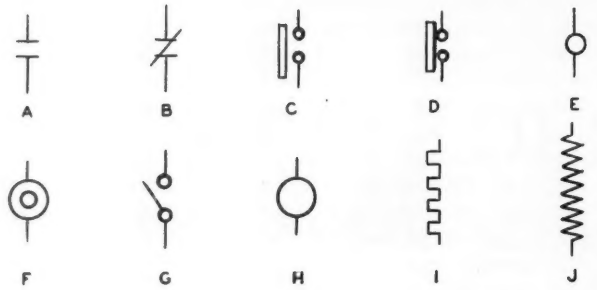


FIG. 1. SYMBOLS USED IN DIAGRAMS ACCOMPANYING THIS ARTICLE

A. Contact normally open.
B. Contact normally closed.
C. Oil circuit breaker auxiliary switch, open when the breaker is open.
D. Oil circuit breaker auxiliary switch, closed when breaker is open.
E. Indicating lamp.
F. Annunciator coil.
G. Knife switch.
H. Relay coil or solenoid.
I. Resistor.
J. Coil.

Figure 2 illustrates the connections of the alternating-current equipment or "speed matching" relays, Fig. 3 illustrates the 48-v. battery connections and Fig. 4 shows the 125-v. exciter connections.

Starting

With reference to Figs. 3 and 4 starting the machine is accomplished as follows:

(1) With the double-pole knife switches 8, 8X, 8Y, 8Z and the 2300-v. disconnecting switches closed assume the water level to the high enough to close the "high water" switch No. 1, in which case the "low water" switch No. 1 will be open. Then a circuit is made from

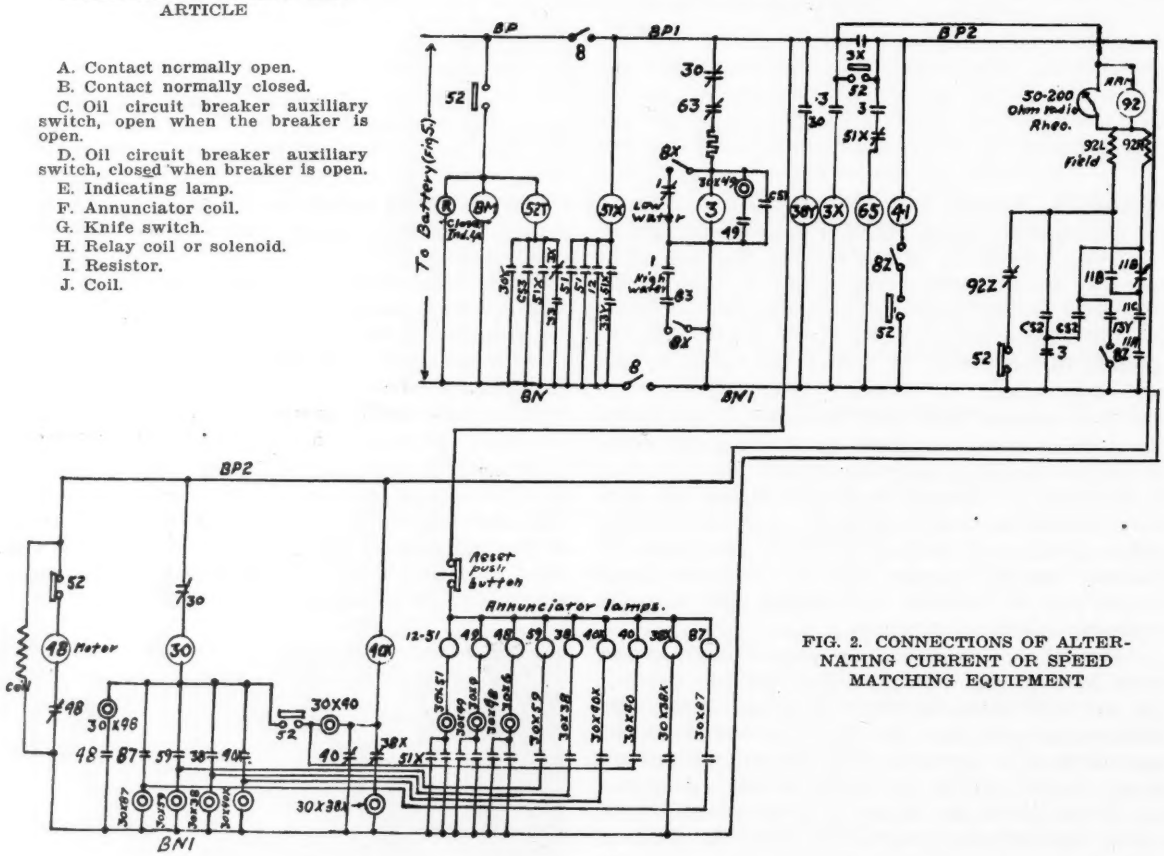


FIG. 2. CONNECTIONS OF ALTERNATING CURRENT OR SPEED MATCHING EQUIPMENT

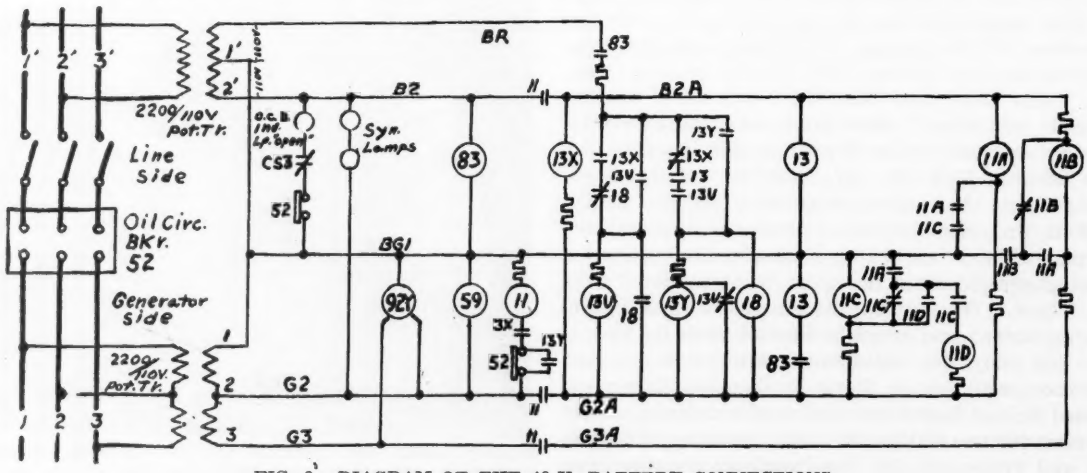


FIG. 3. DIAGRAM OF THE 48-V. BATTERY CONNECTIONS

battery positive BP1 through contacts of lockout relay 30 (normally mechanically latched closed), through contacts of 63 (closed at and above safe governor oil pressure), the 50-ohm resistor, the coil of master relay 3, high-water switch No. 1, contacts of 83 (closed when line is energized), knife switch 8X and battery negative BN1. There is also a control switch CS1 which closes No. 3 coil circuit independently of devices No. 1, 83 and 8X.

(2) Master Relay 3 Closes

When No. 3 closes an auxiliary contact 3 makes to hold the coil energized after No. 1 opens. Another auxiliary contact energizes the governor solenoid 65 through a "break" or normally closed contact of 51X (the auxiliary relay for overload and overspeed relays), and through a "make" contact of 3X, 3X being closed through the remaining "make" contact of 3. The con-

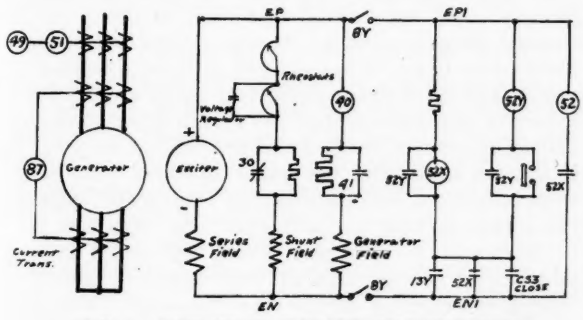


FIG. 4. THE 125-V. EXCITER CONNECTIONS

trol bus BP2 is now energized, starting the field failure timing relay 40X and the protective timing relay 48. Relay 48 is set to lock out the starting equipment should the circuit breaker not close within 5 minutes after the high-water switch closes, its characteristics are discussed in the description of apparatus given later.

(3) The Machine Starts

When the governor solenoid 65 is energized, oil pressure is admitted to the governor mechanism and the gates are opened slowly (owing to a mechanical timing device).

(4) Machine Approaches Synchronous Speed

As the machine increases its speed the voltage of the direct-connected exciter and therefore the a.c. voltage build up causing the governor fly-ball motor 92Y to rotate and regulate the speed of the machine at or near normal. When current flowing into the generator field reaches a pre-determined magnitude field failure relay 40 (Fig. 4) opens thereby deënergizing thermal timing relay 40X.

The voltage regulator now holds the machine voltage at 2300-v. A resistor in the generator field circuit causes the exciter voltage to be approximately 125-v. with a machine voltage of 2300 at full speed—no load, by thus obtaining 125 volts, the oil circuit breaker can be closed from this voltage, resulting in faster circuit breaker action and also reducing load on the small 48-v. battery.

As the generator voltage reaches 80 per cent normal, relay 11 (Fig. 2) closes through a contact of 3X and the oil circuit breaker auxiliary switch 52. The closing of this relay energizes the bus supplying the automatic synchronizer and frequency matching relays.

(5) Generator Is Connected to the Line

When the contacts of generator voltage relay 11 close, energizing the synchronizing bus B2A, G2A, and G3A contacts 11A, 11B and 11C (Fig. 3) of the speed matching relays 11A, 11b and 11C (Fig. 2) complete the circuit of either 92R or 92L (Fig. 3) energizing the governor synchronizing motor to raise or lower the generator frequency in accordance with that of the line. The intermittent or "anti-hunting" feature is accomplished by the induction time element relay 11D (Fig. 2) which on closing its contacts causes the synchronizing motor 92 to be deënergized, the periods of starting and stopping of this motor being dependent on the relative speed of the machine as will be discussed in detail in a latter installment.

When the generator is in synchronism with the line the contacts of automatic synchronizer 13 close and complete the circuit of the coil of circuit breaker control relay 13Y through the "break" contacts 13X of induction time element relay 13X (which is deënergized at synchronism). When 13Y closes the auxiliary control relay 52X closes, completing the circuit of closing solenoid 52 (Fig. 4), thereby connecting the machine to the line.

As the circuit breaker closes, relay coil 41 (Fig. 3) is energized closing contacts 41 (Fig. 4) thereby short circuiting the generator field resistor, but the resulting voltage rise is immediately arrested by the voltage regulator. The absence of resistance in the field circuit now raises the limit of excitation, thus allowing the regulator to take care of all surges withing the machine's rating.

(6) The Machine Assumes Its Load

When 13Y closes (and therefore the circuit breaker) it holds itself in through its auxiliary contact 13Y (Fig. 2), energizes auto-loading relay 18 (Fig. 2) and closes the circuit of synchronizing motor 92 and field 92R (Fig. 3), hence, opening the waterwheel gates until the time element relay 18 closes, opening 13Y indirectly by deënergizing auxiliary synchronizing relay 13U, thereby opening the circuit of 92 at a pre-determined point establishing the load taken by the machine.

In the next article the stopping cycle with protective features will be discussed.

Safety valve blowdown is the reduction in boiler pressure that is necessary to close the valve after it pops. After a valve pops open, the disc will not reseat until the pressure is reduced considerably below the popping pressure.

This pressure drop depends largely upon the seat and valve contour, the characteristic of the spring, and the blowdown adjustments. Every valve has this blowdown adjustment and the A.S.M.E. boiler code limits the blowdown to not more than four lb. below 100 lb. pressure; 6 lb. between 100 and 200 lb.; and eight lb. above 200 lb. pressure.

A reasonable blowdown is desirable, because it permits the fireman to regulate the fire before the valve pops again. A small blowdown means frequent popping with corresponding wear. Furthermore, the closing force is small and the valve does not always seat firmly.

Electricity---What It Is and How It Acts*

PART XLI. A GENERAL REVIEW OF THE PRECEDING CHAPTERS WITH A CONSIDERATION OF THEORY OF COSMIC RAYS. BY A. W. KRAMER

IN CONCLUDING OUR DISCUSSION of radioactive phenomena in the preceding article, it may be well, before proceeding farther in our consideration of the electron, to recapitulate and determine if possible just how some of the conclusions arrived at in this series, are related. To many, no doubt, it may seem that we have digressed endlessly and that some of the subjects treated have little or no hearing on the general theory of electricity under consideration.

However true this may be, it is also true that the electron is so interrelated with everything else in the universe that regardless of the apparent remoteness of some of our digressions, in the end they will be found to fit into our picture. The subject, at best, is one which is extremely involved and because of its far flung nature, is in a state of continual flux; certain aspects of it are changing even as these chapters are being written. This need cause no discouragement; it is due to the continual research which is being conducted in every branch of the field. New discoveries, new theories, new methods in the application of mathematics all bring about changes in the general theory which require the serious student continually to keep abreast of what is happening in the field and to revise his ideas accordingly. Theories are not necessarily permanent; just because an assertion or statement is true at the time it is made is no reason to suppose that it will always remain true. Truth, like many other things in this universe, is relative, it depends upon the accuracy and the existing extent of our knowledge. New advances nullify existing theories and create new ones. Even though superseded by new ones, the old theories cannot be considered to have been in vain for they, probably, form the basis of researches upon which the newer theories are founded. A science or branch of knowledge which suffers no change is at a standstill. As a scientist at the University of Chicago remarked facetiously in a recent lecture, a scientific book should be revised approximately every five years so that all the wrong things in it can be removed and other new wrong things substituted.

In Chapter II after a general introduction, it will be recalled, we began this discussion of electricity with a rather dogmatic description of the electron, its properties and its arrangement in atoms. The forces inherent in the electron were disclosed and the structure of various atoms was explained in terms of the number and configuration of electrons composing them. Chemical and physical properties of materials were also accounted for on the same basis.

Following this electric conduction was discussed, first through gases, then through liquids and finally through solids. This also, was explained on the basis of the electron and upon the electron theory of the structure of matter. The difference between insulators and conductors was discussed and this led to the idea of energy storage in an electrostatic condenser. Energy storage and the motion of electric charges through conductors involved a consideration of magnetic fields, which also were found to be due to the electron.

PROOF OF ELECTRON INVOLVES KNOWLEDGE OF ELECTRIC AND MAGNETIC FIELDS

In presenting these theories, the existence of the electron was taken for granted, that is while definite claims were made for its properties and its existence no positive proof was offered that such an entity as the electron actually existed. It was intimated that such proof existed, but it was delayed purposely because an understanding of the experiments leading up to the discovery of the electron involved a knowledge of electric and magnetic fields and of the structure of matter. So it was not until after the reader had been made somewhat conversant with the action of electric and magnetic fields, that Millikan's experiments were described.

Millikan's work, it was shown, was really the culmination of a long series of experiments by many investigators working on the same problem. This consideration of Millikan's work substantiated the claims made regarding the electron in the previous chapters and made it possible to proceed logically with the discussion of thermionic emission and the theory of the vacuum tube which followed. The subject of thermionics led, naturally to a consideration of the electric arc.

Thus far, the action of the electron had been considered only with respect to itself, not as it affected the space in which it was disposed. The phenomenon of light, however, called for an explanation and it was a logical to seek the relation which might exist between the phenomenon of light and the electron. Light, however, it was shown, was only a specific form of a large general class of radiations so in order to proceed logically it was necessary to account for the class as a whole instead of merely that small portion of it, we term visible light. The light, x-rays, and radio waves were considered in turn, each being accounted for on the basis of the motion of electron, either within the atoms themselves or external to the atoms.

Electromagnetic radiations were shown to cover an enormous range of frequencies, from 20,000 in the case of long radio waves to frequencies of hundreds of millions for x-rays. At the high frequency end of the spectrum, a form of x-ray was shown to exist which have frequencies very much higher than even x-rays. These were shown to be the Gamma rays of radioactive substances and in order to account for these, it became necessary to discuss the general subject of radioactivity.

So our search for knowledge regarding the electron has led us a merry chase through all forms of matter as well as into the less tangible but no less important world of electromagnetic radiation. Although less evident to

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our senses, electromagnetic radiation is just as much a part of this thing we call the universe, as matter, for it was shown[1] that matter has a way of turning into energy. When four atoms of hydrogen combine to form one atom of helium 0.032 of the total mass of the four hydrogen atoms disappears as matter and is radiated out as electromagnetic energy. As a matter of fact, the electron itself is no longer the simple particle it once was and as we have considered it in these articles, but has been shown to be in itself a complex thing acting sometimes as a particle and at other times as a wave, indeed, the wave length of the electron has been determined experimentally and the wave length found was in exact accordance with that predicted mathematically by de Broglie.

The loss of mass in the formation of helium from hydrogen is a fact of considerable importance, for it gives us a clue as to the origin of radiations of frequencies, very much higher than even the gamma rays.

The Theory of the Origin of Cosmic Rays

In Part XXVI[2] in considering the electromagnetic spectrum, a type of radiation was shown to exist at the extreme high frequency end of the spectrum, which were labeled "cosmic rays." As indicated, these radiations are characterized by wave lengths as short as one thousand billionth of a centimeter.

The name used to designate these rays is derived from the fact that they are apparently of cosmic origin; they are found to come to the earth from all directions in space, night and day with practically constant intensity. Although the nature of their origin is still somewhat a matter of conjecture, it is thought that they are the result of the building up complex atoms out of simple hydrogen atoms. Millikan has made extensive researches upon the nature of these rays and in a series of experiments conducted in high altitude lakes in western United States, he found that some 68 ft. of water was required to absorb them. The absorbing power of this amount of water is equivalent to that represented by 6 ft. of lead. Thus, it was evident that these rays were very much harder (more penetrating) than any x-rays or in fact any rays which had before even been imagined. The most penetrating x-rays produced in modern x-ray tubes can not pass through one-half inch of lead, yet here were rays originating somewhere out in space at least a hundred times more penetrating than these. In x-ray technique, high penetration means, high frequency, and according to our present knowledge, the frequency of any ray is proportional to the energy of the sub-atomic change which gives birth to it. The atomic disturbances responsible for the production of these rays therefore involve energy changes far greater than anything we are familiar with. The most penetrating rays that we have known anything about thus far, are the gamma rays of radium. The gamma ray we know[3] is due to nuclear changes within radioactive atoms,—to the transformation of one atom into another. It is scarcely possible then, in considering these cosmic rays, to avoid the conclusion that these still more penetrating rays are produced similarly by nuclear transformation of some sort. But these transformations must be enormously more energetic than those which are taking place in any radioactive changes we know anything about!

At first it was thought that the rays might be caused by the impact of high-speed electrons upon the nuclei of atoms but Millikan showed[4] that the cosmic radiation consisted of two main bands one having different absorption coefficients. One was shown to have an absorption coefficient of 0.35 per meter of water and the other being resolvable into two radiations of absorption coefficients 0.08 and 0.04 per meter of water respectively. This result invalidates the theory of their generation by electronic impact so another explanation is needed.

An explanation is available in the loss of mass which occurs in the formation of helium from hydrogen. The Einstein relation between mass and energy associates any loss of mass with an emission of energy, and there is considerable evidence for a change of mass when protons and electrons are packed together to form a nucleus. The hydrogen atom we know is the simplest atom. If all atoms are built up out of hydrogen atoms then, their mass should be even multiples of the mass of the hydrogen atom, but such is not the case, as we have seen in the mass of helium. The measurements made with the first mass spectrograph[5] were sufficiently accurate to show that this was not true. The theoretical reason adduced for this failure of the law of addition is that, inside the nucleus, the protons and electrons are packed so closely that their electromagnetic fields interfere and a certain fraction of the combined mass is destroyed, whereas outside the nucleus the distances between the charges are too great for this to happen.

Atomic Energy Released Both in the Breakdown and Building Up of Atoms

Aston from his experiments has obtained a curve showing the "packing effect" for all elements. From this curve it is clear that for the lighter elements, of atomic weight less than 80 or so, energy can only be given out when nuclei are built up from protons, and not when they break down. In accordance with this curve the heavier elements give out energy when they break down and this we know is true of the radioactive elements at least.

Now from these mass determinations of Aston it is possible to calculate with a great deal of certainty the amount of energy that can be generated by any sort of atomic transformation. It is possible to determine for instance, the energy, liberated when helium, oxygen and silicon are formed out of hydrogen. Knowing this, we can compute by the aid of quite a reliable formula, the frequency and penetrating power of rays resulting from such transformations.

The observed absorption coefficients of the cosmic radiation as has been stated were 0.35, 0.08 and 0.04 per meter of water respectively. Afterward, from the foregoing considerations of mass and energy, the theoretical absorption coefficients were computed if the observed cosmic rays were produced; 1, by the formation of helium out of hydrogen; 2, of oxygen out of hydrogen, and 3, silicon out of hydrogen. The results came out 0.32, 0.075 and 0.043. These figures it will be seen agree closely with those of the observed coefficients.

[1]Part XL June 1 issue.
[2]August 15, 1929.
[3]Part XXXVII April 1, 1930 issue.
[4]Physical Review XXXII 533 1928.
[5]An instrument, for analyzing positive rays, that is rays of positively charged particles, into a spectrum of focussed lines.

Thus the evidence that the cosmic rays are the result of the creation of common elements out of primodial elements is not only qualitative, but quantitative. The elements on the basis of which the above calculations were made, furthermore, are among the most common of all elements. Oxygen and silicon are found in abundance not only on earth but in the stars and the run as well. It is quite possible then that the cosmic rays are signals sent to us, of the continuous birth of the common elements or perhaps we should say, of the continuous rebirth of the universe.

Thus we are able to account for the existence of all forms of electromagnetic radiation from the longest radio waves to the shortest cosmic ray on the basis of electronic motion. Considered as a whole, electromagnetic radiations in free space are all alike—they all travel at the same speed and the mechanism of propagation is the same. It is only when we consider these radiations in relation to matter that we can classify them into different groups. The difference between the groups are due to the difference in the nature of the vibrators or oscillators which produce them.

Damper Windings for Synchronous Machines

THEIR FUNCTION AND METHOD OF CONSTRUCTION FOR VARIOUS TYPES OF MACHINES

DAMPER WINDINGS have been used on synchronous motors for many years but operating engineers are not always certain as to what their function is and they are sometimes at a loss to account for the peculiarities that appear in the various types. This subject was discussed recently in an article by B. C. Seaman, of the Ridgway Works of the Elliott Co., in Powerfax. By special arrangement with the Elliott Co., we are permitted to present the substance of this discussion in this article.

The construction of the damper winding varies with the speed and service for which the machine is intended; however, its general construction is always similar to that of the rotor winding on a squirrel-cage induction motor. It consists of bars embedded in the pole faces and short-circuited by low resistance end rings. The winding is usually made in segments to provide for the removal of any pole and coil without disturbing the others. Figure 1 illustrates the construction of the damper winding of a medium-speed synchronous motor, and Fig. 2 that of a slow-speed machine. The damper winding of a generator differs but slightly from that of a motor of corresponding speed.

Damper windings are supplied to perform a definite service. On a generator, they prevent hunting; on a motor, they provide a means for starting. In order to show clearly the foregoing action, it is necessary to examine the operation of a synchronous machine.

It is well known that in a synchronous machine there

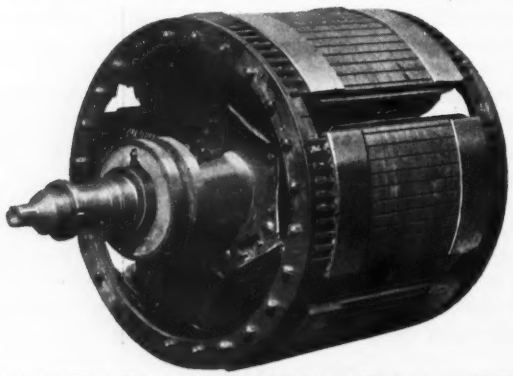


FIG. 1. ROTOR OF MEDIUM SPEED SYNCHRONOUS MOTOR SHOWING DAMPER WINDINGS

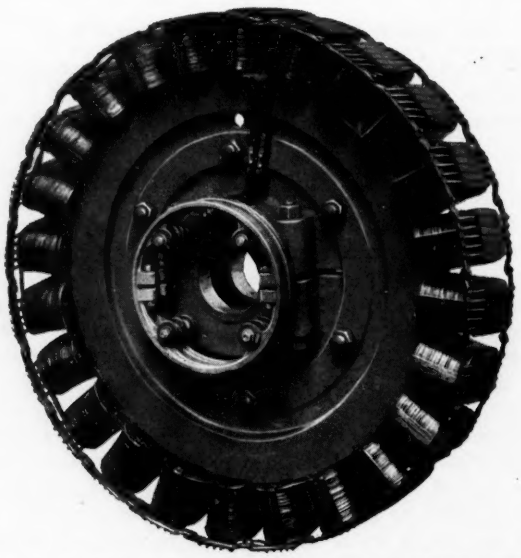


FIG. 2. ROTOR OF A SLOW SPEED MACHINE WITH DAMPER WINDINGS

is a revolving magnetic field set up by the armature winding that travels around the stator at synchronous speed. The rotor also travels at synchronous speed, but it is always displaced in phase position with the stator by a small angle as shown in Fig. 3. The two are not unlike the spokes in a wagon wheel, which are displaced from each other, yet travel with the same speed. The salient pole on the rotor leads the induced stator pole in the case of a generator, and lags it in the case of a motor.

This angle is proportional to the amount of load and is approximately 20 electrical degrees for a machine of normal design.

Since the damper bars are embedded in the rotor pole faces, the rotor flux threads the bars and has no effect on them. As long as the angle between the two fields remains unchanged, the flux due to the revolving stator field also threads the bars and there is, therefore, no cutting of flux by the damper bars. No voltage is generated in them and no current flows through them.

When the torque on the shaft changes, due to pulsations in the engine or some other cause, the angle be-

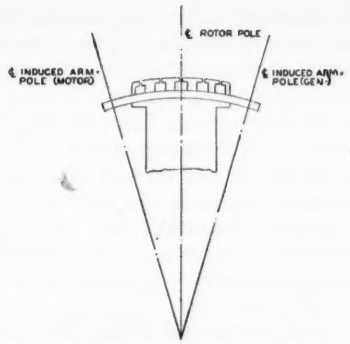


FIG. 3. DISPLACEMENT BETWEEN ROTOR AND STATOR OF GENERATOR AND MOTOR

tween the two fields varies slightly, although it tends to hold to a mean or average position. As this angle varies, the damper bars sweep through the flux of the rotating stator field mentioned above, and heavy currents are induced in the bars. These currents set up torques in such a direction as to offer a powerful resistance to the tendency for a shift in position. The damper winding has, then, a powerful steadying action upon the machine and tends to prevent it from hunting.

This action takes place in both the synchronous generator and motor. In the case of the motor, however, the damper winding has another very important function in that it provides a means for starting. A synchronous motor is started exactly as if it were a squirrel-cage induction motor and when it has attained its full speed as an induction motor, the field is applied to pull it into step. The damper winding in this case acts exactly as the rotor winding of a squirrel-cage induction motor.

MINIMUM TORQUE REQUIREMENTS OF USUAL SYNCHRONOUS MOTOR APPLICATIONS

	Starting Torque	Synchronizing Torque
Centrifugal Pumps, 1800 to 720 r.p.m.	25	40
Centrifugal Pumps, 3600 r.p.m.	20	50
Ammonia Compressors	35	25
Air Compressors (Belted)	40	25
CO_2 or SO_2 Compressors	75	40
Jordan Engines	40	25
Line Shafts (average)	60	30
Motor-Generator Sets	30	20
Rubber Mills, 200 to 100 r.p.m.	200	120
Cement Machinery, 1800 to 720 r.p.m.	250	110
Blowers	25	40

The starting torque of a synchronous motor is that percentage of full-load torque that it will start from rest. The pull-in torque is that percentage of full-load torque that the machine will pull into step after it has come up to ninety-five per cent speed and the field is applied. In other words, it is the point at which the speed-torque curve of the machine, running as an induction motor, crosses the ninety-five per cent speed line. The pull-in torque is sometimes called the synchronizing torque.

Figure 4 shows the speed-torque curves for a synchronous motor running as an induction motor with various types of damper windings. Curve A is that of a low-resistance, curve B, that of a high-resistance, and curve C, that of a double squirrel-cage damper winding. These types of windings will be explained later.

As in the case of an induction motor, the starting torque of a synchronous motor upon the losses in the rotor at starting. These losses are (1) the iron loss in the pole faces, (2) the loss in the field winding, and (3) the loss in the damper winding. With the laminated pole construction used in all but high-speed machines, the iron loss in the pole faces is low and the resultant torque from this part is, therefore, low. The torque due to the losses in the field winding is alternating and is of little use in starting the machine. It is apparent then that the starting torque of a synchronous motor depends almost entirely upon the damper winding.

Changes in the construction of the damper winding may be made to obtain various starting characteristics. In general, these changes may produce the following effects:

(1) Raise or lower the starting torque.
(2) Raise or lower the pull-in torque.
(3) Vary the starting kv-a. or current inrush.

Some of the factors that enter into the proper selection of the damper winding are as follows:

Since the starting torque of the synchronous motor depends on the loss in the rotor at starting, a high-resistance damper winding with its high loss will give a high starting torque; however, the full load speed of the machine running as an induction motor also depends on the rotor loss. A high rotor loss will give a high slip, a low maximum speed, and, therefore, a low pull-in torque. This may be seen by examining the curves in Fig. 4. It is apparent, then, that this type of winding may be applied to a machine requiring a high starting torque and a low pull-in torque. On the other hand, a low resistance winding should be applied when a low starting and high pull-in torque is required.

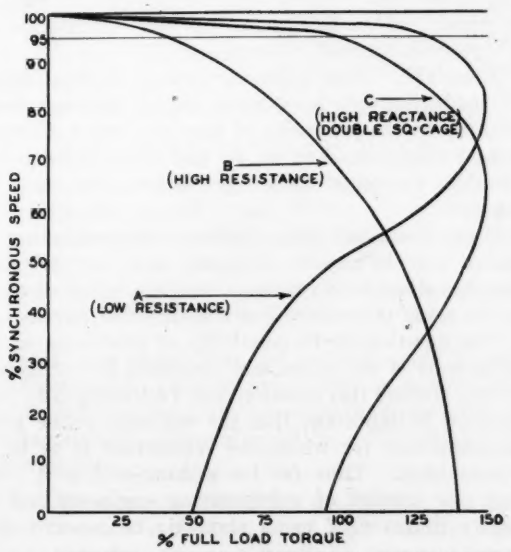


FIG. 4. CURVES SHOWING TORQUES DEVELOPED BY DAMPER WINDINGS

Now a highly reactive damper winding will also give a high starting torque, due to the high resistance of magnetic materials, and a comparatively low pull-in torque. In addition, it has the advantage of reducing the starting kv-a. or current inrush, since the starting kv-a. of a machine depends on the total reactance of the machine and as the reactance of the damper winding is an important part of the total reactance, this type of winding is frequently used on motor-generator applications where the pull-in torque required is low.

In order to combine the advantages of low current inrush and high pull-in torque, a double squirrel-cage type of damper winding has been developed. This winding is used on special applications and the relative torques developed by it are shown in Fig. 4.

The characteristics outlined above are so closely interrelated that one of them can rarely be changed without affecting the others. It then becomes a matter of selecting the proper winding to give the required torques and at the same time give the lowest possible starting kv-a.

The accompanying table has been made to show the minimum torque requirements of the usual synchronous motor applications in per cent of the full load torque. These torques are based on the usual starting methods; that is, in the case of a compressor, unloading valves or clearance pockets are used, while centrifugal pumps and blowers are started with either the intake or the discharge closed, and motor-generator sets are started with the generator running light. Since these applications are all suitable for full voltage starting, it should be noted that torque guarantees are made on the basis of full voltage starting and that the torque developed will vary as the square of the applied voltage.

Ideal and Practical Refrigerant Requirments*

THE SELECTION OF A REFRIGERANT DEPENDS UPON SIZE OF LOAD, TEMPERATURE PLANE AND REQUIREMENTS FOR SAFETY. BY J. E. STARR AND J. B. CHURCHILL

IN THE broadest sense of the term almost any of the millions of chemical compounds known might be termed a "refrigerant," for under certain specified conditions any could be used as a medium to extract heat. The term, however, as usually applied has a far narrower meaning and for the purposes of this paper the discussion is confined to those fluids capable of being used in a practical way for taking up heat. These may be roughly classified into three distinct groups.

Class I. Those substances having a comparatively low boiling point and which extract heat during their passage from a liquid to a gas. This class comprises practically all of the fluids commonly called refrigerants such as ammonia, carbon-dioxide, methyl-chloride, sulphur-dioxide, ethyl-chloride and iso-butane.

Class II. Those substances having a higher boiling point at atmospheric pressure where the passage from a liquid to a gas involves large volumes of the gas, such as water, carbon-bisulphide, carbon-tetrachloride and methylene-dichloride (Carrene).

Class III. Those substances where the heat changes are made entirely in a super-heated gas and heat is taken up by the expansion of that gas from a more compressed condition, such as, air and other gases not condensable, except at very low temperatures and high pressure.

Aside from the above classes mentioned, other substances may be capable of being used as refrigerants. Certain salts take up heat on solution, other substances can be made to produce low temperatures mechanically.

The question of the possibility of producing an ideal refrigerant is one sometimes discussed in refrigeration circles. Before this question may be intelligently talked about, it is important that the engineer define exactly the conditions for which the refrigerant is to be considered ideal. Thus for ice making and cold storage work the verdict of refrigerating engineers has been largely in favor of using ammonia on account of the range of temperatures obtainable at ordinary pressures and on account of reasonable construction of apparatus. Strong arguments may be made for the use of carbon dioxide but the refrigerating world has generally settled on the use of apparatus using ammonia in larger operations. In small operations other factors become more important and fluids are used to advantage having a specific volume as great as methyl-chloride or in some cases as great as ether.

From a strictly theoretical point of view, the following properties might be ascribed to an ideal refrigerant once the engineer had defined the limits of its use.

(1) It must admit of convenient and reasonable manufacturer.

(2) It must have a range of temperature at reasonable evaporating pressures, always positive (above 14.7 lb. abs.), adapted to take up heat on the required levels encountered.

(3) Its corrosive properties should be such that no corrosive action takes place within any metals or alloys used in ordinary construction.

(4) It should have a distinct odor enabling leaks to be easily detected.

(5) It should be nonflammable and non-toxic and not injurious to human life or health.

(6) Exposed to great heat or in contact with fire it should not decompose into toxic gases which would endanger the life or health of human beings or hinder fire fighting operations.

Many of the fluids now used as refrigerants will answer the first four requirements, but none of them will answer the fifth and sixth, especially when used in the larger operations.

The selection of a refrigerant so far as its physical properties, or the first four points mentioned as requisites for an ideal refrigerant are concerned, must depend in a great measure on, first, the size of the operation (load) and second on the temperature plane at which it is desired to take up heat.

*Abstract of paper presented at the meeting of the American Society of Refrigerating Engineers at Atlanta, May 7-9.

With the second class of refrigerants methods of handling other than piston and cylinder displacement are appropriate such as, for instance, the ejector or centrifugal method. Water, for example, with a boiling point of 212 deg. F. has a volume of 715 cu. ft. per min. for one ton of refrigeration when boiled out of a brine solution at 20 deg. F. and a pressure of 2½ mm. of mercury. This immense volume at this extremely low pressure could not well be handled by a piston and cylinder operation and that either centrifugal or ejector action must be used. There is an outstanding example of commercial success with this class of refrigerants handling large volumes at comparatively low pressures. The refrigerants in this case being methylene chloride, CH_2Cl_2, or similar high boiling liquids. Others have proposed to use the ejector system with operations using water or other high boiling refrigerants of this class.

In regard to the third class of refrigerants we find that outside of air, few or no attempts have been made to use other gases of this class as refrigerants for general purposes. The theory and practical application of the air machine is well known. Refrigeration by compressed air is generally considered a thing of the past as it can not compete with refrigeration by the use of condensable gasses; two and one-half to three and one-half times the power being required. For the reason that air and water are the only known refrigerants possessing ideal physiological properties, many attempts have been made to adapt them for use in the small machines where the occupational risk is great, but none have been brought to a commercial success in present day practice.

Question of Toxicity Varies in Importance with Type of Plant

In approaching the fifth and sixth divisions above referred to, namely, the requirements as to the toxicity of the refrigerant, it may be said generally that a non-toxic gas in all cases would be desirable, but in large operations such as in ice making and cold storage the hazard is generally an occupational one. The buildings are usually so constructed as to render escape easy in case of a rupture of the piping; besides, only an extremely small part of the public are subjected to any hazard that may exist and this small part is composed of adults who are there only part of the time and are supposed to be alert and acquainted with the hazard and who can easily escape. Also, these people are especially trained to the prevention of leaks and are supplied with all appliances for combating them, should they occur. Therefore, in occupational hazards of this kind there does not exist the insistent demand for a non-toxic refrigerant.

It would seem, however, that the demand for a refrigerant that is non-toxic as far as the quantity used is concerned, is an imperative requirement in such cases as homes or apartment houses, where men, women, and oft-times helpless adults and infants continually reside. It seems not good engineering to subject them to the possibility of the escape of sufficient refrigerant to injure, especially in view of the fact that the home or apartment house can be provided with mechanical refrigeration without the possibility of danger.

When any refrigerant other than air or water is used it is necessary to take the question of quantity into most careful consideration. This is of far more importance than the degree of toxicity of the refrigerant used. For example, the safe use of a refrigerant of comparative high toxicity, such as ammonia, might be cited as exemplified in the present gas-fired machine, which at least in the smaller sizes does not contain enough toxic refrigerant to do harm if it all should escape. So far as the writers are aware this is proved by the fact that no injury to life or health has been recorded as caused by the use of this machine. The same might be said of many of the others, but unfortunately, not all.

It is probable that none of the known or proposed refrigerants would be absolutely safe in extensive operations with large systems such as the so-called multiple systems; no matter what safeguards it is possible to throw round them. Even the safeguards proposed by the Safety Codes of this Society are inadequate to prevent possible injury or loss of life, especially in case of fire.

A New Refrigerant

Considerable interest has been aroused in refrigerating circles by the recent announcement by both Thomas Midgley, Jr., and the United States Bureau of Mines, of the possibility of a new refrigerant being found in one of the formerly little known chemical compounds, namely, dichloro difluoro methane, OF_2C1_2. This substance was discovered and described a number of years ago by Professor Fred Swartz of the University of Ghent, Belgium.

Dr. Midgley, on April 8, 1930 in a talk before the American Chemical Society, at Atlanta, Ga., described the properties of this refrigerant and alluded to the possible use of other organic fluorides as refrigerants.

From the facts Mr. Midgley states this refrigerant has the following properties:

I. Formula, $CC1_2F_2$

Molecular weight, 120.0
Weight of one liter at 32 deg. and 760 mm., 5.376 grams
Density (Air = 1), 4.158
Wt. of 1 cu. ft. at 32 deg. and 760 mm., 0.3357 lb.
Volume cu. ft. per lb. 5 deg., 760 mm., 2.822
32 deg., 760 mm., 2.979
86 deg., 760 mm., 3.309

(Above derived from molecular weight)

II. Density of liquid (Water = 1), 1.40

Boils at –18 deg. F. at 760 mm.
Specific heat of liquid, 0.224
Latent heat at –18 deg. F., 39 calories per gram (70.2 B.t.u. per lb.)
Latent heat at 86 deg. F., 34 calories per gram (61.2 B.t.u. per lb.)

III. It was stated that the material could be made by the action of antimony trichloride on carbon tetrachloride, that the yield was about 80 to 90 per cent, and inferring that the material could be produced at a reasonable price.

IV. The corrosive properties at 175 deg. are satisfactory for such metals as monel and stainless steels, but unsatisfactory for such metals as bronze, all types of brass, aluminum or magnesium alloys.

V. It is said to be extremely non-toxic as reported in the findings of the U. S. Bureau of Mines, the result of whose work showed it to be much less toxic than other refrigerants; animals withstanding for long periods of time a concentration of some 20 per cent by volume.

VI. The material is non-inflammable under all ordinary conditions. Mr. Midgley did not say how this material would react when coming in contact with fire or what its decomposition products would be.

In regard to this material, too little is known of its physical properties to estimate whether or not they are satisfactory from a constructive standpoint. A very rough estimation based on the data available would show that about 5.33 lb. would be required per ton of refrigeration, approximately 16 cu. ft. displacement; this would be 2.23 times that of ammonia.

All that is known of its toxic properties is that it is only toxic in much larger quantities than other refrigerants. But whether or not it can be used in large systems one is at the present time unable to say. It is not assumed that Dr. Midgley wished to indicate that it would have any value in the commercial field, where at present ammonia is mostly used; It may, however, have great value in mining operations, room-cooling and for certain phases of marine refrigeration. Its low toxicity may also fit it for many uses connected with household refrigeration.

Mr. Midgley said that there is no thought of replacing the refrigerants now in use as he inferred that these were perfectly satisfactory. We can hardly regard this statement as correct in the light of our treatment of the subject. The greatest need of such a refrigerant is in the replacing of the highly toxic and dangerous sulphur-dioxide now used in domestic machines in quantities greater than safe practice would advocate, as well as in replacing other toxic fluids in such installations where the quantity of refrigerant constitutes a hazard to health.

As far as physical properties are concerned no fluid now known or likely to be discovered will fill all requirements of an ideal refrigerant for all purposes. As to toxicity we can only look to a bettering of conditions. No fluids other than air or water will ever be found completely free of all toxic properties.

Boiler Feedwater Pressure Regulation

Excess-Pressure Regulator in Combination with Water-Level Controller Maintains Proper Boiler Feed. By E. T. McCarthy

REGULATORS designed to maintain a constant feedwater pressure by controlling the steam supply to the feed pump have long been in use. More recently the excess or differential type pump regulator has come into favor. This latter type is designed to regulate the steam supply and consequently the speed of a turbine-driven or reciprocating pump in such a way as to hold the feedwater pressure a definite amount higher than the steam pressure at particular points.

Motor-driven boiler feed pumps may be equipped with either one of two types of regulators to accomplish the same result. If a variable-speed motor is used, rheostatic speed regulating equipment may be applied, which holds the pump discharge pressure at a constant excess above the steam pressure. If a constant-speed motor is used a regulator installed on the pump discharge will throttle the water to a constant excess above steam pressure.

Standard regulators, available for any of the above applications, satisfactorily perform the service for which they are designed. It is to be noted, however, that this service is the maintenance of a constant differential between feedwater pressure at or near the pump discharge and steam pressure at the pump. None of these regulators is designed to hold a constant excess where a constant excess is desired, that is, between the inlet and outlet of the water level controller at each boiler nor can they be expected to do so. There are two reasons for this; the variation in steam friction between the drum and the point where the regulator is connected and the variation in feed line friction between the pump and the boiler inlet. A simple example, assuming the following data, will make this clear:

	Light Load Lb.	Heavy Load Lb.
1—Drum pressure	275	275
2—Steam pressure at pump	270	260
3—Steam friction	5	15
4—Water pressure at pump	330	320
5—Excess pressure at pump	60	60
6—Water pressure at level controller inlet	315	280
7—Feed line friction plus static head	15	40
8—Excess pressure across controller	40	5

Although the regulator maintains a 60-lb. differential at the pump in each case the increase in steam and water friction reduces the useful excess at the level controller from 40 lb. to only 5 lb. at the time the level controller is required to pass more water.

It is obvious that no kind of regulation at the feed pump can maintain a fixed differential at several boilers. Any change in the rate of feeding a particular boiler causes a change in the pipe friction and a change in the differential at each of the other boilers. In many cases, particularly where pipe sizes are ample and changes of load are moderate, the maintenance of a constant excess at the pump results in a sufficiently constant excess at the level controller to permit satisfactory water level control. In the case of large boilers, however, or where a number of boilers are fed by the same pump, with fluctuations in load and rate of feeding which always occur, the variation in differential at each controller may seriously affect the feed control.

Suppose, for example, the water level controller has adjusted itself to such a port opening as to feed the required amount of water when a differential of 20 lb. exists. If now, a neighboring boiler begins to take more water or if the steam pressure in the boiler drum should rise, the excess pressure across the level controller might easily drop from 20 lb. to 5 lb. and a corresponding decrease in the rate of feeding would result until the

water level in the drum had dropped sufficiently to cause the level controller to open and feed more water. It will easily be seen that the level controller has to adjust itself not only to different rates of evaporation but a greater part of its movements are necessitated by changes in pressure either of the feedwater at its inlet or of the drum at its outlet.

If these pressure changes are rapid or considerable, there may be serious fluctuations of water level in the drum as the level controller cannot possibly anticipate a change in differential. It cannot act until the change in rate of feeding has caused a sufficient change in water level to operate the thermostat or float. Meanwhile, wide variations in rate of feeding and consequent irregularity in feed temperatures have occurred.

Constant differential may be obtained at each boiler by means of an excess pressure regulator in connection with the water level controller at each boiler. A regulator of this type which is installed at the inlet side of the supply of water to the boiler. Further, any slight leakage of water from the ¼-in. connection between the diaphragm chamber and the upper mercury pot causes the mercury to rise in the upper pot and become lower in the lower pot until the lower end of the pipe column is unsealed. Then, for every drop of water leakage, a drop of water will enter the bottom of the mercury column and rise rapidly through it on account of the 1 to 13 difference in density. Leakage may occur continually from the ¼-in. connection mentioned without interfering with the successful operation of the regulator, as such leakage is constantly made up from the feed line.

Special arrangement of the excess-pressure regulator has been provided for cases where the pressure regulator should be placed before the level controller as shown in Fig. 3. In this case the regulator opens as the diaphragm moves downward so that leakage or failure of any of the piping will cause the regulator to open. It will be noted that the steam passes through a close-

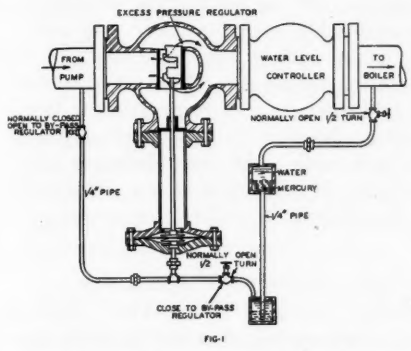


FIG. 1. BOILER FEED IS CUT OFF IN CASES OF LEAKAGE OF DEVICE

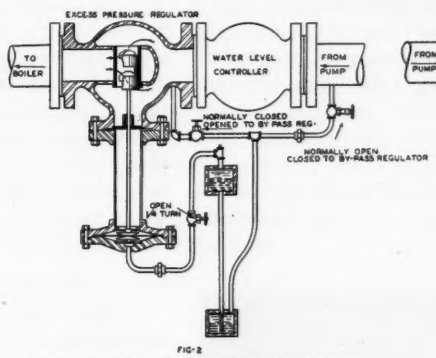


FIG. 2. VALVE IS HELD OPEN IN CASES OF LEAKAGE OF DEVICE

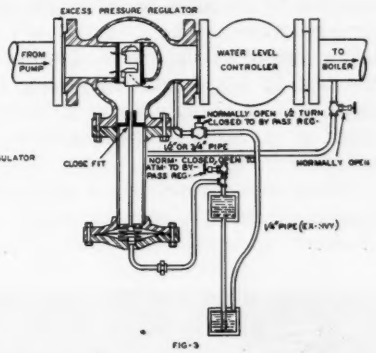


FIG. 3. ADVANTAGES OF SECOND ARRANGEMENT RETAINED

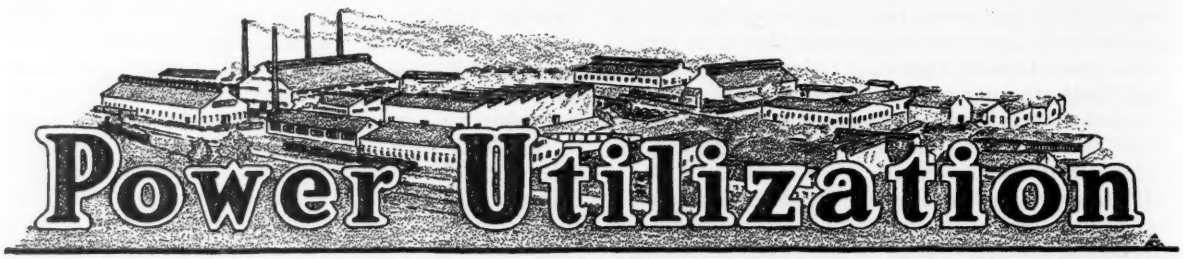
any water level controller and which acts practically as a reducing valve but maintains, at its outlet, a pressure which is a definite amount higher than the pressure at the level controller outlet is shown diagrammatically in Fig. 1.

It will be noted, in Fig. 1, that any failure or serious leakage from the ¼-in. pipe conections will reduce the pressure under the diaphragm and allow the valve to close thereby reducing or completely shutting off the rate of feed to the boiler. Failure of the diaphragm will have the same result. Any leakage of water from the ¼-in. connection between the diaphragm chamber and lower mercury pot allows the mercury to drain down in the column gradually reducing the differential which the regulator will maintain. To avoid these practical difficulties the arrangement shown in Fig. 2 has been devised. In this case the pressure regulator is between the level controller and the boiler drum. It is assembled as a back-pressure value holding the pressure at its inlet a constant amount higher than the pressure at the level-controller inlet. Theoretically at least, the one arrangement is equivalent in results to the other with no advantage for either.

Practical advantages, however, are all with the Fig. 2 arrangement. It will be noted that in this case the valve opens as the diaphragm moves downward, consequently leakage or breakage of any of the ¼-in. piping allows the regulator to open wide and does not endanger fitting baffle, not a stuffing box. This separates the outlet part of the regulator valve from the space above the diaphragm. A pressure connection is made from the outlet side of the controller back to the water leg of the regulator so that the diaphragm is controlled by the pressure at the controller outlet and not by the pressure at the controller.

This special arrangement was developed to avoid a difference between the pressure at the outlet side of the controller and the pressure in the float chamber. It will be readily seen that the pressure in the controller float chamber is the same as the pressure in the boiler drum. The pressure at the outlet end of the controller valve is ordinarily only slightly higher than the drum pressure if no unusual resistance is introduced between the controller valve and the boiler drum. The installation of a regulator on the outlet side of the controller valve would introduce a certain amount of resistance.

In some cases where the pump delivers an unusually high pressure which the regulator has to throttle, the resistance introduced by the partially closed regulator valve might be considerable. There would then be a tendency for water to leak from the outlet of the controller valve along the valve stem into the float chamber and raise the level there somewhat above the true level of water in the drum. This, of course, would result in unsatisfactory level control. The arrangement shown in Fig. 3 avoids this condition and still retains the desirable features of arrangement Fig. 2.



Cool Drinking Water Systems

RECIRCULATION, MAKE-UP, AND REFRIGERATION REQUIREMENTS. BY L. M. JORDAN

DUE TO UNNATURAL conditions of living, brought about by housing human beings, three elements essential to life must be artificially provided, viz., light, air and water. The first two are usually adequately taken care of by lighting and ventilating engineers but the last is too frequently given little consideration. Usually it is thought that, if water which will do to drink is provided somewhere about the premises, that is sufficient.

Good water is not only a necessity but is of positive benefit. "Drink plenty of water" is the watchword of every up-to-date physician but many fail to heed this advice simply because the water to which they have access is unpalatable, even if pure. A man wants water, not only good but also refreshing and, if it is not cool enough he simply isn't going to drink enough of it to maintain good health.

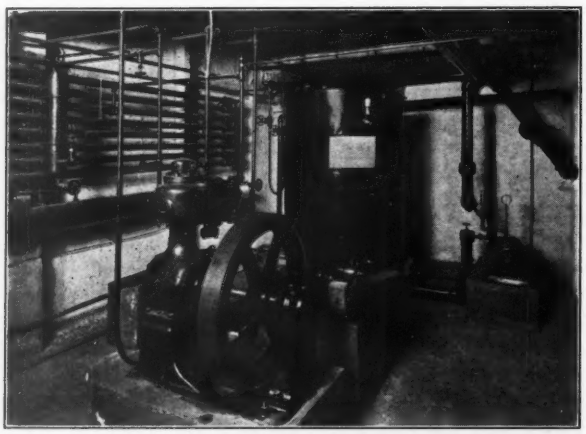


FIG. 1. TYPICAL REFRIGERATING PLANT FOR DRINKING WATER

PLENTY OF WATER NECESSARY FOR HEALTH

There is more than the purely humanitarian side of the question to be looked at. The industrial employe whose body has too little water is likely to lay off from sickness, which obviously will affect the profits of the plant, labor turnover and quality of products.

In the majority of cases there is but one way to remedy the condition. The common method, placing water kegs or tanks about the plant, cooled by blocks of ice, has several objections, to say nothing of its expense. First, the water will be at varying temperature, for the iceman may be late on his rounds, so that employes work a considerable period without cool water; also occasionally the ice will be exhausted early in the day. Second, it is inconvenient. Third, it is unsanitary as ice water is dangerous if persons drink it freely when heated, such as laborers in heat-treating plants, blacksmith shops and mills. An overwhelming thirst is hard to control and, if when heated one drinks cold water too freely, he is likely to suffer from cramps and other ill effects.

REFRIGERATION FOR PROPER TEMPERATURE

Proper continuous provision of drinking water is only by means of refrigeration, directly in or in close proximity to the plant, applying the refrigeration directly to the water, which is circulated through loops or circuits to points convenient for workers. Mechanical refrigerating systems, like that in Fig. 1, are practically automatic and need but little space. Such systems are practically the same for an office building, mill or factory, differing only in details. The plant consists of a refrigerating machine, cooling tank, distributing circuit and good insulation, supplying convenient bubblers or drinking fountains.

In Fig. 2 is shown the outline of a system commonly employed for tall buildings, where the head pressure from the city main or other source is sufficient to raise the water level in the distributing circuit several feet above the highest fixture. Water is cooled in the tank containing the expansion coil of the refrigerating plant and is circulated through the distributing system by a multi-cylinder plunger pump or a small centrifugal pump. Minimum of power is consumed in keeping up the circulation since head is balanced in the return line against that in the outgoing, leaving the water friction in the system as practically the only work for the pump.

MAKEUP SUPPLY

In this system, a closed cooling tank is employed strong enough to carry the pressure of the system. Above the highest fixture, a balance tank is connected, through which makeup is admitted to the circuit, as water is used. The float valve acts automatically when the water level falls.

In Fig. 3 is shown a system employed where water must be pumped to the fixtures. In this case, the pres-

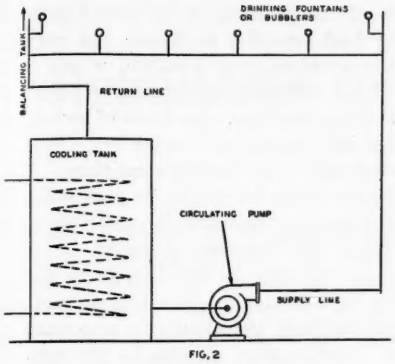


FIG. 2

FIG. 2. COOLED WATER SYSTEM FOR CITY PRESSURE

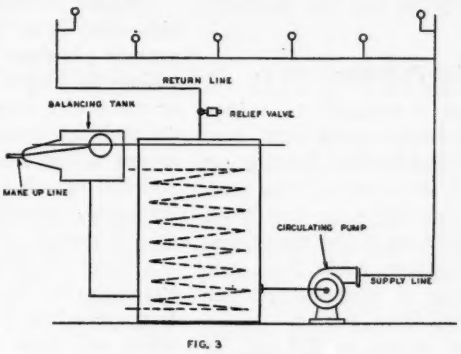


FIG. 3

FIG. 3. SYSTEM FOR HEAD PUMPED ON SYSTEM

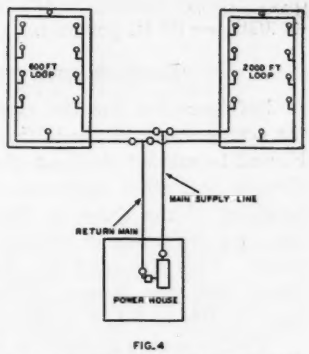


FIG. 4

FIG. 4. PIPING OF A WATER DISTRIBUTION SYSTEM

sure necessary to elevate the water to the highest fountains is supplied by the circulating pump which operates against a head created by the use of a relief valve, located in the return line of the circuit just above the cooling tank. This valve is set to maintain the required pressure and the pump has to overcome the resistance thus offered in addition to the friction in the pipes.

In this case, a less expensive cooling tank may be used, since it works at atmospheric pressure. Water supplied by the pump in excess of that consumed from the circuit returns to the cooler through the relief valve. Supply in the cooling tank is maintained by means of a balance tank, located at bank level.

Amount of Water and Refrigeration Needed

One of the first points to be considered in laying out a drinking water system is the number of employes to be supplied, and the average rate of consumption by each employe. This will differ with the occupation, as a man working in a heat-treating plant will obviously consume more water than an office employe. Conservative estimates based upon experiments place the average consumption (used and wasted) by factory employes at 0.25 gal. per hour. In determining refrigeration needed, allowance must be made for line absorption from the atmosphere along the distributing circuit.

As a typical installation assume a plant consisting of two main buildings requiring two distribution loops, one of these 600 ft. long to supply 100 men, the other 2000 ft. long to supply 300 men. In most cases, for plants of this size, a 1-in. pipe line can be used for the distributing circuit. Heat is absorbed through this size line, when well insulated, at a rate of 0.152 B.t.u. per lineal foot, per degree difference in temperature, per hour.

Proper temperature for drinking water is from 45 to 50 deg. F. It is customary to cool the water to 45 deg. F. and allow for a 5-deg. rise in the circuits. With a maximum average atmospheric temperature in the plant of 85 deg. F., the average difference in temperature between the water in the system and the atmosphere is 37.5 deg.

Heat absorption in the 2000-ft. circuit will be

$$2000 \times 37.5 \times 0.152 = 11{,}400 \text{ B.t.u. per hour}$$

As the water is cooled 5 deg., at 1 B.t.u. per degree per pound, the quantity of water required to be circulated is

$$11{,}400 \div 5 = 2280 \text{ lb. per hr., or } 2280 \div 8.3 = 274.6 \text{ gal. per hr.}$$

Makeup will be, $300 \times 0.25 = 75$ gal. per hr., hence the total quantity pumped per hour will be $75 + 274.6$ or 349.6 gal.

Velocity of flow is found as follows:

Cu. ft. per min. $= 349.6 \div [60 \text{ (min. an hr.)} \times 7.48 \text{ (gal. per cu. ft.)}] = 0.728$ cu. ft. per min. The cross sectional area of a 1-in. pipe $= 0.006$ sq. ft. The velocity at the outgoing end of the circuit $= 0.728 \div .006 = 121.3$ ft. per min.

Calculations for the 600-ft. loop are by the same method.

Makeup is, $100 \times 0.25 = 25$ gal. per hr.

Heat absorbed by the loop is, $600 \times 37.5 \times 0.152 = 3420$ B.t.u. per hr.

Water to be circulated for cooling needed is, $3420 \div 5 = 684$ lb. or 82.4 gal. per hr.

Total water is $25 + 82.4 = 107.4$ gal. per hr.

Quantity is, $107.4 \div (60 \times 7.48) = 0.238$ cu. ft. per min.

Velocity is, $0.238 \div 0.006 = 39.7$ ft. per min.

If connections to the loops is by main lines of somewhat larger pipe, as in Fig. 4, assuming that the length of these lines is 100 ft. and that 1¼-in. pipe was used, the total length of the main lines would be 200 ft.

Total circulation for both loops is $0.728 + 0.238 = 0.966$ cu. ft. per min.

Sectional area of the 1¼-in. main line is 0.0104 sq. ft.,

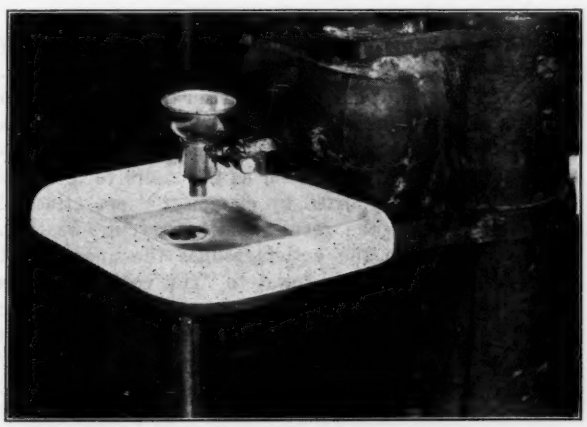


FIG. 5. FOUNTAINS SHOULD BE CONVENIENT AND EASILY CLEANED

therefore the velocity in the outgoing line will be, 0.966 ÷ .0104 = 93 ft. per min.

Refrigeration to Be Provided

Refrigeration for the system is required to reduce the temperature of the initial makeup water to 45 deg. F. and to extract the heat absorbed by the distributing circuits and other apparatus of the system. The temperature of the water in the outgoing main line is 45 deg. or a difference of 40 deg. between it and the atmosphere. This size pipe line will absorb 0.173 B.t.u. per lineal foot, per degree difference in temperature, per hour, or 100 × 0.173 × 40 = 692 B.t.u. per hr.

Total water supplied to the system is, 457 gal. or 3793 lb. per hr. in round numbers.

The main line absorbs heat at a rate of 692 B.t.u. per hr., hence temperature rise in the outgoing supply line is

$$692 \div 3793 = 0.182 \text{ deg. F.}$$

Since the outgoing water should enter the loops at 45 deg., the temperature leaving the cooling tank would have to be, 45 — 0.18 = 44.82 deg. F., to allow for the rise in the connecting main.

Total quantity of water returned to the cooler is 2280 + 684 or 2964 lb. per hr.

Temperature rise in the return main is, 100 × 0.173 × 35 ÷ 2964 = 0.204 deg. F.

This added to the 50 deg. temperature of the water returned to this return main equals 50.21 deg.

If makeup water comes at 75 deg., this must be reduced to 44.82 deg., also the return water must be reduced from 50.21 to the same temperature.

Total makeup water is, 100 gal. or 830 lb. an hr., which must be reduced through 30.18 deg. requiring heat abstraction of, 830 × 30.18 = 25,000 B.t.u. an hr.

Water returned to the cooling tank is 2964 lb. per hr., to be cooled through 5.4 deg. Heat required to be abstracted is, 2964 × 5.4 = 16,005 B.t.u. per hr. Then, total heat to be abstracted from makeup and return water is, 25,000 + 16,005 = 41,005 B.t.u. per hr.

One ton of refrigeration equals 288,000 B.t.u. per 24 hr., so that the refrigeration required for the system is, 41,005 × 24 ÷ 288,000 = 3.41 t.

In calculating the capacity of the refrigerating machine it is always best to allow at least 1 ton over and above the theoretical figures, as a margin of safety and to take care of extensions of the system.

The value of good insulation on all surfaces affecting the load on the machine cannot be stressed too greatly. This includes all outlet loops, riser supports, clamp hangers and the like. No through metal connections should be permitted, as these cause a loss of refrigeration. Refrigerated lines, such as the risers to the bubblers, should be supported by clamps that are attached to the outside of the insulation to prevent sweating. Although loops to the outlets reduce the quantity of water wasted in waiting for it to "run cool," all lines should be run as nearly straight as possible to minimize frictional resistance. Dead ends at the fountains are a source of loss of both water and time, as the volume of water contained in the dead end is drawn off before cool water issues. Pressure in the distributing lines should be sufficient to cause a free flow of water from the bubbler orifices.

Where the area of the grounds to be served is considerable, it is the best practice to locate the refrigerating plant as near centrally as possible, which will reduce the length of the distributing circuits. Character or make of refrigerating machine, also type of drinking fountain or bubbler is a matter of choice but the one shown in Fig. 5 is well suited to factory conditions. The pedestal type is also desirable for mills. It goes without saying that whatever the type selected, it should be such as will permit of ready and thorough cleaning.

Water supplied, in addition to freedom from harmful bacteria, should be thoroughly clear and attractive. It may be free from bacteria, yet cloudy in appearance, which will make it objectionable. If this be the case, it can be clarified by proper filtering, using sand, charcoal or fabric to remove the foreign matter and air held in suspension. Much help can be obtained from refrigerating contractors, when planning an installation.

Power required to drive the compressor will depend upon the suction and condensing pressures maintained, and upon the type of compressor, whether single or double-acting. With an ammonia system employing a simple, single-acting compressor and maintaining a condensing pressure of 145 lb. per sq. in. and 15 lb. suction or back pressure, this will be about 1.2 hp. per ton refrigerating capacity or for 4.41 t. will be 5.3 hp.

Power required for the circulating system is that necessary to elevate the water to the highest fixture, including the lift to the balance tank and the figures given include the friction of the pipes. Assume that both circuits rise to a height of 50 ft., including the rise to the balance tank, and that the main or feeder circuit is horizontal, requiring no lift, the horsepower is found by multiplying the gallons pumped per minute by the total lift and dividing the product by 4000.

We found that the total water pumped through circuits was, for the 600-ft. circuit, 107.4 gal. and for the 2000-ft. circuit, 349.6 gal., a total of 457 gal. per hour. Therefore, 457 ÷ 60 (minutes) = 7.62 gal. per min. Then, 7.62 × 50 ÷ 4000 = 0.095 hp. The total horsepower required is the sum of 5.3 and 0.095 or 5.4 hp.

For photographs and some data the author is indebted to the Armstrong Cork & Insulation Co.

Combined operation of industrial plants and central station with a view toward more economical power generation has been discussed and to a certain extent practiced. Probably the reason this is not done more often is because the industries find it difficult to agree that the saving to the utilities is the increment fuel cost only.

Not only are utilities taking surplus power from some industries, but in some cases they are operating the plants themselves or building power plants to take care of the industrial needs. In one interesting installation in New England, the power company installed a turbine in the industrial plant as a cheaper alternate than building a second 10-mile line to insure service.

Fuel saving was also an objective, and the fuel saving of six mills per kilowatt hour is evenly divided. Power generated is fed to the system on the utility side of the meter and the power used paid for on the regular power bill but receives credit at the rate of three mills for power generated by the steam necessary for process and industrial purposes.

Regulation for Pressure and Heating Steam

Floating Auxiliary Turbine, Reducing Valves, Sizes and Connections. By Charles L. Hubbard

PRACTICALLY every plant using steam requires various pressures from live steam down to atmospheric or below. If exhaust or bled steam is used for process work or heating, provision should be made for supplementing with live steam at times of peak demand when power load may be low.

Hospitals, for instance, need 60 to 70 lb. for laundry work, 20—30 lb. for sterilizing, 5—10 lb. for cooking and 1—3 lb. for heating.

Pressure reduction may be made by a non-condensing engine or turbine with the power generated as a

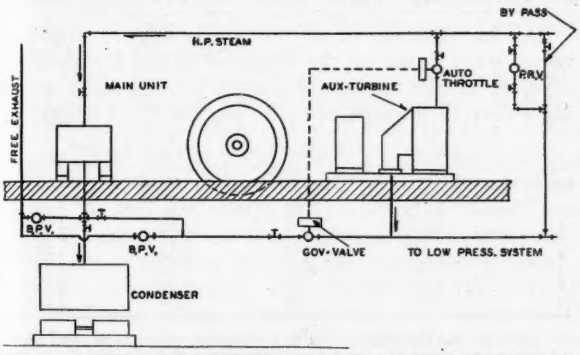


FIG. 1. AUXILIARY TURBINE FLOATS ON THE SYSTEM AS REDUCING VALVE

byproduct at low cost, and delivering some 85 per cent of the heat in the live steam for heating. Pressures above exhaust must then be provided by bleeding between cylinders of a compound engine, from some stage of a turbine or by reducing valves using live steam. Such valves reduce pressure by throttling, which dries out and may slightly superheat the steam, so that heat is not lost but the superheat may be an objection for some kinds of process work.

Variable Process Demands

If large amounts of low-pressure steam are required at irregular intervals, it may be advisable to use a non-condensing turbine as reducing valve, connected as in Fig. 1. It will be arranged to start and stop automatically as pressure varies in the low-pressure main, the governing valve being similar to a pump governor and acting on the throttle of the turbine. Power will be delivered to the switchboard through automatic voltage and synchronization control, relieving the main unit of that much load.

This arrangement permits of running the main unit condensing during the non-heating season, taking process steam from the turbine exhaust, a condition frequently desirable in textile and similar plants.

Pressure and Temperature Reduction

Superheating of steam in large industrial plants necessitates reduction of both pressure and temperature for process work. If large amount of steam are needed, use of an auxiliary turbine as above is the simplest method but for smaller quantities, a desuperheater will be required in connection with a reducing valve.

Various types of desuperheating devices are on the market, some employing a spray, others bringing the superheated steam in contact with films or drops of water, still others making heat transfer in a closed feedwater heater of special construction. In any case, the object is to remove a sufficient amount of heat from the steam to bring its temperature down to the point of saturation at the given pressure. The heat thus removed is used in heating or evaporating the cooling water, so that neither water nor heat are wasted.

With steam at 200 lb. gage pressure, it will require approximately 5 gal. of water at an initial temperature of 70 deg. to desuperheat 1000 lb. of steam having 80 deg. of superheat; and 7 gal. when 120 deg. of superheat are to be removed. This is on the assumption that all of the cooling water is evaporated into steam, which is not usually accomplished in practice.

One simple arrangement for reducing pressure and temperature of superheated steam is shown in Fig. 2. In this case a spray nozzle is placed in the high-pressure pipe, discharging against the flow of steam. Following this is a separating chamber for removing any excess water which remains after the steam has been cooled to the saturation temperature, then pressure is reduced by a valve beyond the separator. With this arrangement the low-pressure steam may be slightly superheated, due to wire-drawing in the valve and if, for any reason, this is objectionable, pressure reduction may take place before desuperheating, in which case it will be necessary to use a reducing valve designed especially to withstand high temperatures. In the patented devices of this type the spray head is usually placed in the separating chamber.

When the desuperheated steam is to be used in an engine whose valve gear is of a type subject to distortion at high temperatures, it is important that no excess water be carried into the cylinder.

Some engineers, therefore, prefer the closed-heater arrangement or, if a spray is used it is recommended

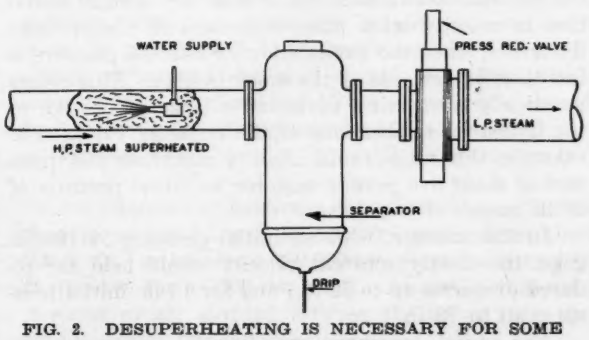


FIG. 2. DESUPERHEATING IS NECESSARY FOR SOME PROCESS WORK

that a second separator be placed in the pipe beyond the reducing valve as a precaution against entrainment.

Sizes of Reducing Valves

Often the mistake is made of using too large a valve, common practice being to make it the same size as the low-pressure main, or at least to give it a capacity approaching that. Since velocity of flow of steam through a long run of pipe and through a short nozzle or orifice is quite different for a given difference in pressure, the size of port should be based upon the weight of steam to be handled under the given pressure difference regardless of the size of pipe connections. Then proportion the inlet and outlet upon an assumed velocity for the high- and low-pressure steam lines.

When the valve is too large, so that it operates at a fraction of its capacity, wire-drawing is greatly increased, and the life of the valve is reduced by scoring of the seat, which also tends to make its action more or less unsatisfactory, even after a comparatively short time.

Reducing valves supplying steam for the warming of buildings are particularly liable to this action because

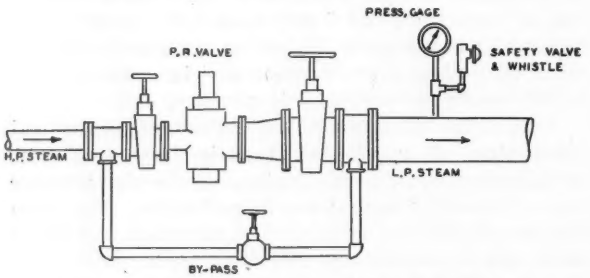


FIG. 3. REDUCING VALVE AND ACCESSORIES

the average heating load for the entire season is only about one-third the maximum. If the valve is too large for the full load, which is often the case, it must be excessively large the greater part of the time and must, therefore, operate in a nearly closed position.

For the best results, the valve should be so designed as to stand fully, or nearly open, at maximum load, which will still give a good clearance under average operating conditions, thus reducing wire-drawing and scoring to a minimum and so adding to the life and satisfactory working of the valve.

Area of Port or Orifice

In considering the flow of steam through an orifice, the peculiar condition is found that only a small variation in velocity takes place regardless of the pressure difference, when the absolute low or reduced pressure is less than 58 per cent of the absolute high. This covers practically all heating work and a large proportion of the industrial applications of the reducing valve. For example, this ratio would allow a maximum low pressure of about five pounds gage for an initial pressure of 20 lb. gage.

In like manner, with an initial pressure of 100 lb. gage, this nearly constant velocity would hold for reduced pressures up to 52 lb.; and for 15 lb. initial pressure, up to 72 lb.

For initial pressures exceeding 20 lb. (gage) the velocity under the above conditions will run from 800 to 900 ft. per sec., or around 850 ft. for pressures of 80 to 100 lb., which are usual in combined power and heating work.

If reduction of one-half is allowed for wire drawing and friction at bends and fittings, we may count on a velocity of at least 425 ft. per sec., or 25,500 ft. per min. under practical operating conditions.

Table I shows on this basis, the pounds of steam discharged per minute through circular valve ports of different diameters.

TABLE I. REDUCING VALVE DATA

Diam. Valve Port, in.	Lb. Steam per min.	Diam. Inlet, in.	Diam. Outlet, in.	Diam. Bypass, in.
½	15	¾	1	¾
¾	25	1	1½	1
1	40	1¼	2	1¼
1¼	70	1½	2½	1½
1½	95	2	3	1½
2	155	2½	4	2
2½	220	3	5	2½
3	340	3½	6	3
4	585	5	8	4
5	920	6	10	5

As an illustration of the over-sizing of reducing valves when based on the diameter of the low-pressure pipe, let us take the care of a 10-in. heating main, allowing a drop in pressure of ¼ lb. per 100 ft. in length.

TABLE II. CONSTANTS FOR STEAM FLOW

Diam. Pipe in.	Internal Area, Sq. ft., A	Gage Press. lb.	Vol. 1 lb. Steam, Saturated	S. Cu. ft, Supht. 150°
3	0.042	100	3.88	4.74
4	0.076	120	3.33	4.13
5	0.120	140	2.92	3.62
6	0.175	160	2.60	3.23
7	0.243	180	2.34	2.91
8	0.321	200	2.13	2.65
10	0.500	220	1.96	2.51

Steam carried by this pipe under the assumed conditions will be approximately 190 lb. per min., which is close to that discharged through a 2¼-in. orifice under the ordinary operating conditions of a pressure-reducing valve. If the valve port were made 10 in. in diameter, the same as the connecting low-pressure main, it is evident that it would have to operate in a nearly closed position to maintain the required pressure difference upon the two sides of the valve.

TABLE III. STEAM FLOW AT LOW PRESSURE

Dia. of pipe, in.	Pounds of steam flow per min. ⅛ lb. drop	¼ lb. drop
3	6.0	8.6
4	12.7	18.1
5	22.5	32.2
6	36.2	51.7
7	52.7	76.7
8	75.6	108.0
10	134.4	192.0
12	213.5	305.0

When the port of a reducing valve is proportioned for the maximum quantity of steam which is to pass through it, as previously described, the only actual requirements, as to the sizes of inlet to the valve body and outlet from it, are that the former shall be of sufficient capacity to supply the full quantity at all times under existing conditions, and that the latter shall be large enough to carry it away after expanding to the lower or reduced pressure.

These are fixed by the makers of the value in an assumed ratio to the maximum port opening, which they have found to operate satisfactorily.

For average conditions the sizes given in Table I should be ample and may be connected into the high- and low-pressure lines by suitable reducing fittings, if found necessary.

Computation of sizes of mains varies with the custom and experience of the designing engineer.

For runs of ordinary length, say 100 to 200 ft., it is customary to allow a steam velocity of 6000 to 10,000 ft. per min. for high-pressure work. Even higher velocities are employed for superheated steam.

The weight of steam discharged, based on velocity of flow, is given by the formula: $W = A V \div S$; in which W is pounds of steam discharged per minute, A is internal area of pipe in square feet, V is velocity of steam, in feet per minute and S is volume of one pound of steam at the given pressure and temperature. Some values for A and S are given in Table II.

Velocity in low-pressure heating mains is commonly based on a given drop in pressure per unit of length. Table III gives the pounds of steam discharged per minute through pipes of different diameters, with pressure drops of ⅛ and ¼ lb. per 100 ft. in length.

Pressure reducing valves should always be provided with bypasses, Table I, and cutout valves, so that they can be inspected or taken out for repairs without interruption of the steam supply.

As the valve in the bypass is used as a throttle when passing steam into the low-pressure main, it should be of the globe type, since this distributes the flow of steam better over the valve seat and is less subject to scoring. The cutout valves should be of the straightway or gate type, as they are always fully opened or closed, hence are not subject to scoring. Other details in this connection are a pressure gage in the low-pressure main, so located as to be readily seen when setting the valve and a small pop safety valve connected with a whistle for giving an alarm, should the reducing valve fail to work properly and the pressure rise above a predetermined point. Typical connections are shown in Fig. 3.

Back-Pressure Valves

In heating systems utilizing exhaust steam, a back-pressure valve is always used. This is a relief valve of large size designed to open at low pressure. In use it is placed in the outboard branch of an exhaust pipe, as shown in Fig. 1, in order to maintain a definite pressure within the exhaust system and at the same time prevent the pressure from rising too high. In well-designed systems of exhaust heating, this pressure should not exceed 2 or 3 lb. gage, and many plants are operating satisfactorily on one pound or less. The reducing valve and back-pressure valve work in combination, the former admitting live steam automatically when the quantity of exhaust falls below the normal heating requirements and the pressure begins to drop, while the back-pressure valve opens when there is a surplus of exhaust and the pressure in the heating system rises slightly above normal.

Soapstone for Gasket Treatment

When no graphite is available to treat a flange gasket or other washer used on pipe joints to prevent sticking, thoroughly rub powdered soapstone on the surface of the gasket. This will be quite as effective for this purpose as graphite. The soapstone can be used dry or mixed with kerosene to form a paint-like mixture.

Lakeview, Canada. James E. Noble.

Induction Motor Noises

Often, induction motors are noisy in operation, due to three causes: magnetic, electric and windage.

Magnetic noises vary from a faint hum to a high-pitch shriek, sometimes accompanied by vibration. This is usually due to loose iron or to the vibration of the iron in the rotor core under the influence of a high-frequency current. It is also influenced by the design of the magnetic circuit, flux density and other details, these being a matter for the designer to correct.

These noises remain practically constant at all loads but increase with the frequency, a 60-cycle motor being much more noisy than one of 25 cycles.

Noises due to the effect of current resemble a low growl or heavy rumble which is often accompanied by severe vibration. This noise is due to unsymetrical electrical circuits in the machine, the noise varying with the load, loudest when starting and when operating at full load. If the circuits in the rotor have different resistances, so that the current divides unequally through the paths, there will be current noises. This may be caused by high-resistance joints in the rotor coils, or some electrical fault in them. These can be found by testing.

Another possible cause is the stator coils being of unequal strength. In this case, the magnetic field will not be uniform all round the rotor, which will give rise to vibration and noise. The coils should be tested to see whether of equal strength. Unequal air gaps between the rotor and the stator will also cause a non-uniform magnetic field and therefore the same trouble. These gaps should be checked at frequent intervals and when the width of the gaps begins to vary much the bearings should be adjusted.

Windage noises are caused by projecting parts on the rotor, which catch the air as they rotate and cause a whistling sound. Partly choked or peculiarly shaped ventilating ducts may also cause windage noises. These windage noises are not harmful but are irritating to the ears. Windage noises can be distinguished from those due to either current or magnetic causes by running the motor up to full speed, then shutting off the current. Either magnetic or current noises will cease as soon as the current is shut off; while noises due to windage will continue, although decreasing in intensity as the rotor slows down.

London, England. W. E. Warner.

To Remove Rust from Steel

Steel that has rusted can be cleaned by brushing with a paste compound made in accordance with the following formula: Potassium cyanide, ½ oz.; castile soap, ½ oz.; whiting, 1 oz.; water, sufficient to form a paste. Afterward, the steel should be washed with a solution made by dissolving ½ oz. of potassium cyanide in 2 oz. of water. Potassium cyanide is a poison!

Denver, Colo. H. L. Kauffman.

An analysis of modern power plants shows that the floor space per kilowatt of capacity varies from about 0.4 sq. ft. per kw. for a 200,000-kw. plant to about 4 sq. ft. per kw. for a 3000-kw. plant. As a rule, this space is about evenly divided between the boiler room and turbine room.

Stack Razing

HAVING MOVED to its new plant location on the Detroit River front, the Michigan Alkali Co. of Dearborn in abandoning its old plant had the problem of razing its stack. The stack, which was built in 1902, was 258 ft. high, 17 ft. inside diameter and 24 ft. outside diameter and 35 ft. outside diameter at the base. It weighed 3500 t. and 1,100,000 bricks had been used in its construction.

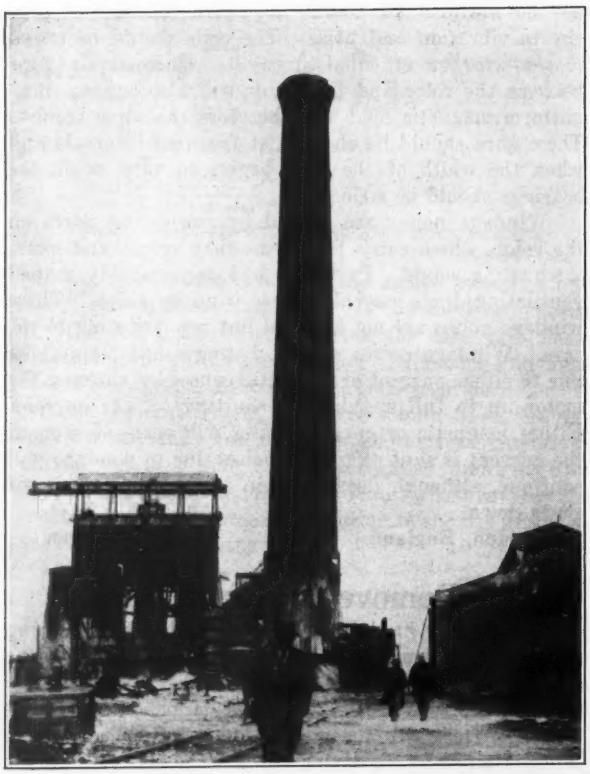


FIG. 1. STACK BEFORE BLAST SHOWING BUILDING AT LEFT WHICH WAS NOT DESTROYED

It was necessary to drop the stack at the left as shown in Fig. 1 to save the building which is shown at the right. This required the stack to drop on the side of the breeching opening. Heavy dynamite charges were placed along the left side and a light charge was placed along the right side with the object of breaking

FIG. 2. ON THE WAY! UPPER BREAK OCCURRED WHERE STACK LINING ENDED

up the stack so it would not fall too far from its base. This was accomplished fully, the farthest brick falling within 115 ft. of the base. Approximately 250 lb. of dynamite was used. The stack, blown from its base, crumbled to the ground as though it were telescoped. The break shown in Fig. 2 near the top of the stack, came at the point where the inside lining ended. It took 8 sec. from the time of the blast for all debris to reach the ground.

Dearborn, Mich. J. J. RUIZ.

Chattering of Brushes on Slip Rings

BRUSH TROUBLES are generally associated with commutator-type machines. Such troubles, however, are not uncommon on slip ring or induction motors even on field rings of synchronous motors. Chattering or sparking of the brushes on slip rings may be due to the brush angle. Brushes held loose in the holders or brush holders placed too far away from the rings, especially the latter, affect the angle of the brushes in many types of brush holders.

Soft spots in the rings also cause chattering. In such cases the rings should be carefully ground to a

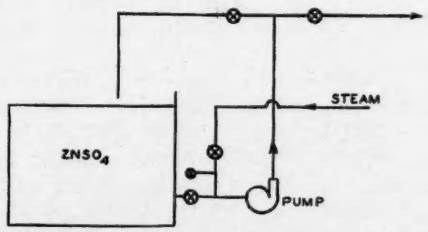
true surface. It is better to grind them than to turn them in a lathe as a truer surface can be obtained in this way and on rings that are inclined to give trouble, the truer surface that is given them and the more accurately the brushes are fitted, the less likely they are to give trouble. Where a motor is started under a heavy load, the current flowing from the brushes to the rings may be sufficient to cause burning of the surface of the ring unless the brushes are liberally proportioned and accurately fitted. Other causes of chattering are worn shaft or bearings in which a sprung shaft is run.

If the machine is inclined to be sensitive at the brushes, any defects that may cause radial movement of the brushes should be removed. If the shunts that connect the brushes to the holders become loose, the springs may carry sufficient current to overheat them and destroy their temper, a condition that must be remedied before satisfactory operation can be obtained.

Hobart, Ind. HARRY J. ACHEE.

Rapid Steam Heating Method for Liquids

RECENTLY I had occasion to heat up tanks of zinc sulphate solutions using exhaust steam at a pressure of only ½ to 1 lb. As no open heater was desirable, a rather novel method was used. A pump had been installed to pump out the tank, so a valve was placed close to the tank and the steam line connected to the suction of the pump as shown in the line diagram illustrated.



STEAM BLOWN IN AT SUCTION SIDE OF PUMP HEATS LIQUID WHICH IS PUMPED

This method permitted the closing of the liquor suction valve sufficiently to draw a suction of several pounds at the pump, resulting in a good flow of steam into the liquor and fast heating.

Wilmington, Del. L. H. HAUPT.

Steam Jet Ash Conveyor Cost Reduction

MOST ENGINEERS can tell you how much they are paying a ton for their coal and how many pounds of water they are evaporating per pound of coal, or the cost per thousand pounds of steam but few engineers seem to know what percentage of ash they get with their coal or what it is costing them per ton of ash to dispose of it. Many engineers will tell you what type of coal burning equipment should be used when they know the characteristics of the coal but these same men hesitate to suggest what class of ash-handling equipment to employ and usually admit they know practically nothing about their ash-handling costs.

In many cases, closer attention to ash handling will save money. A more careful and frequent examination of the ash pile will frequently show a needlessly high carbon content, indicating careless hand cleaning of fires, improper adjustment of coal feed or of air supply. An examination of an ash pile after a rain or after some water has been thrown over the ash pile, making the carbon stand out in an unmistakable way, will prove glaringly how much carbon is being wasted and will indicate whether or not it would pay to rake over the pile. Recently it was necessary to investigate an ash-handling installation, which had originally been economically operated but which had, in the course of time, become unsatisfactory, wasteful and troublesome. Furnaces must be kept in good condition or they will not function. Prime movers and generators must be kept in good shape or they will break down. These are in plain sight at all times, hence they receive proper consideration and close attention. The ash-handling system, however, is not so in evidence, hence receives abuse and it does not appear to be as important since if it fails it is possible to get along without it. Moreover, moisture, corrosion and abrasion hasten deterioration while the class of labor operating the ash-handling system is usually of a lower grade than that having charge of boiler room and engine room. For these reasons, the ash-handling system is often allowed to get into a condition of disrepair.

Labor turnover is also greater with ash-handling crews than with engine room crews. Consequently, it is easy for these men to hold down a job without being properly instructed in the operation of ash-handling equipment, and how to minimize operating costs. Usually nobody about the plant knows the steam consumption necessary to move the ash when a steam jet type of ash conveyor is used and as no means is available for measuring it, the increase of steam consumption may occur without the fact being known. It is suggested, therefore, that the engineer in charge see that the man responsible for handling the ash be familiar with the principle of operation and that he may be made to appreciate the importance of watching the following conditions and requirements and follow strictly the suggestions given.

Manufacturers of steam jet ash conveyors might print cards to be hung in the boiler room stressing among other things the following points:

Steam pressure: Be sure that the steam pressure is correct and that the nozzles are adjusted for the actual pressure. A frequent reason for waste of steam is that the pressure is other than that intended for the nozzle.

Keep system tight: Keep all flanges and joints tight, otherwise suction will suffer and steam consumption will be increased.

Before blowing ash: Before turning on the steam be sure to observe the following: Drain oil line; feed only dry ash; drain all condensation; be sure all water is removed, otherwise ash will clog up the line; break up all clinker and large lumps; never open steam line until everything is ready to blow; begin feeding ash immediately after steam throttle is wide open, starting to feed the ash nearest to the steam unit and working backward; never overload but feed steadily, keeping the supply of ash moving in a steady stream at full capacity of the conveyor; close throttle valve immediately after ash has been removed, for considerable steam may be.

wasted through delay due to not closing this valve tightly.

Use your ears: The kind of noise is a good indication of performance. A loud noise from the suction indicates an empty conveyor; when the noise dies down perceptibly, there is overloading. There will be a characteristic noise at full load and this is the sound to obtain.

Failure to follow the foregoing suggestions may result in using twice as much steam as should be required. Neglecting the fixed charges on the ash-handling system and the depreciation due to abrasion, the cost of operation is, of course, the cost of steam. Using twice as much steam as should be required is equivalent to paying twice as much as should be necessary to handle the ash. Besides seeing that the proper steam pressure is used and that the nozzles are properly adjusted for the actual pressure, it is important that the air vent at the end of the suction line farthest from the steam unit be left open and unobstructed. Moreover, it is important that this opening shall be of the same size as the internal diameter of the pipe.

Because the steam jet type of ash conveyor consists so largely of castings, pipes and fittings, many engineers feel that they can save money by securing their own patterns and having their castings made. Apart from the fact that special iron should be used in order to withstand the abrasion of the ash, purchase of castings encourages more costly operation due to neglect of important factors of design. Because the steam used for the steam jet type of ash conveyor is rarely measured, great extravagances may creep in unobserved. The rated steam pressure of the system should be adhered to. Considerable saving can be made if ash can be blown at the time when there is excess steam, as when shutting down at five o'clock or at noon.

Chicago, Ill. C. G. Crowley.

Longitudinal and Girth Seam Strengths

There appears to be, even at this late day, more or less mystery in certain circles as to why the longitudinal joint in a boiler or drum should be of butt strap, double, triple or quadruple riveted construction although the girth seam may be only of a single riveted lap joint.

A first class butt strap joint should have an efficiency of at least 93 per cent, while the lap joint efficiency will be only 56 to 58 per cent but the strain on the heads is only half that at the butt strap joint, therefore, the lap joint is even stronger in proportion. For instance, take the formula for the bursting pressure of the shell:

$$T \times \text{t.s.} \times E \div R = P$$

in which,

T = thickness
t.s. = tensile strength
E = efficiency of the joint
P = bursting pressure
R = radius

The formula for the girth seam is:

$$T \times \text{t.s.} \times C \div A = P$$

in which,

T = thickness
t.s. = tensile strength
C = circumference
A = area
P = bursting pressure

If we assume a seamless tube of 10 in. diam., one inch in thickness, with a tensile strength of 60,000 lb., and reënforced heads to withstand greater pressure than the tube itself, case one will read:

$$(1 \times 60{,}000) \div 5 = 12{,}000$$

and case two will read:

$$[1 \times 60{,}000 \times (10 \times 3.1416)] \div (10^2 \times 0.7854) = 24{,}000$$

which shows that only half the strength of the longitudinal seam is required in the girth seam.

But a far shorter solution may be had as follows: In both cases, cancel the T and t.s. and the first reads:

$$1 \div R = P$$

In the second case, instead of the diameter times 3.1416 for the circumference, use the radius times 6.2832 and the area, $R^2 \times 3.1416$, then the formula will read:

$$(R \times 6.2832) \div (R^2 \times 3.1416) = P$$

Then, by cancellation, we have $2 \div R = P$, which shows that the second case has twice the resistance of the first case.

Lawrence, Mass. C. J. Wilder.

Boiler Baffle Walls Need Expansion Joints

Experience has proven that it is possible to use steel reinforcing rods of proper size in curtain walls where the temperature is not too high and this is now good practice, but in baffle walls where the temperature of the gases surrounding the baffle is considerably higher reinforcing rods are likely to give trouble. Steel does not have the same coefficient of expansion as plastic. This difference in expansion and corrosive action may cause cracking and breaking. On one job in the writer's experience, a foreman used rods that were too large even for the curtain wall. As a result the curtain wall cracked and the contractor was obliged to reconstruct the wall, sustaining a considerable loss.

Satisfactory results are obtained by using expansion joints in the walls. Recent experiments at the Engineering Experiment Station of the University of Illinois have proven that the expansion of a plastic is variable and not directly proportional to temperature as is the case with steel boiler tubes.

Furthermore, it is found that the movements of the tube banks in a given boiler are not always in the same direction but change decidedly. The top tubes may tend to move one way while the lower tubes tend to move in another direction. In a test made by the Engineering Department of Drexel Institute, Philadelphia, the pressures at various temperatures caused by the expansion of heated structures held to a fixed length, were as follows:

Temp. Reading	Increase	Load Reading	Increase
70	0	10,000	0
212	142	66,000	56,000
230	180	114,000	104,000

These figures make it clear why expansion joints are always desirable.

Newark, N. J. W. F. Schaphorst.

In Australia, coals with 50 to 64 per cent moisture are being successfully burned on step grates by means of preheated air.

Questions and Answers

Dashpot Rebound Causes

WHAT CAUSES a dashpot on a Corliss engine to rebound? With a heavy load on the engine, the dashpots work all right but as soon as the load goes off they will rebound when they drop and the hook has to drive them down every time. The knock off cams are all right. B. N. M.

A. Several different things may cause rebounding of a dashpot. It operates all right when the engine is under heavy load for then the lift is ample to provide the necessary vacuum under the plunger to insure a prompt return when the valve is tripped. If the lift is small, the plunger is not raised enough to create the proper vacuum to return the plunger to its place.

If the dashpot is lubricated with a heavy oil, this will retard the prompt return which is so much desired. Sometimes, if the spring in the check valve is too strong, it will prevent the escape of the air on the return stroke, which sucks in when the plunger is raised. Scant lubrication of the steam valves will also increase the trouble.

Butt and Lap Joints for Boilers

1. WHY IS THE thicker and wider strap of a double butt strap joint placed on the inner side of the shell while the narrower strap is placed on the outside?

2. Why is the lap of a lap joint boiler always turned down on the inside? B. N. M.

A. The inside butt strap is thicker and wider than the outside because it is intended to take the tensile strain to a considerable extent and to stiffen the joint against bending; while the outside strap is intended more to hold down the edges of the sheet.

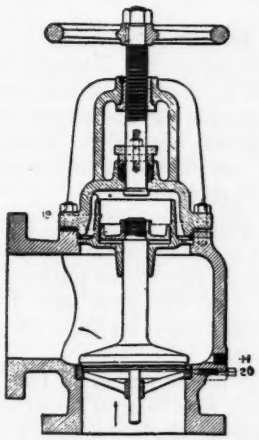
With the heavier strap on the inside, it is easier to make the edges of the sheet conform to the curvature of the strap than it would be if the straps were reversed or were alike. It would be possible, of course, to make the straps alike but experience has shown that the present method of construction is better mechanically and allows of better calking.

2. If the lap turned up on the inside of the shell, a ring or shelf would be provided all around the inside upon which deposit could easily collect and corrosion form. By turning the lap down on the inside, this condition is avoided.

Overcoming Nonreturn Valve Chatter

ON OUR BOILER, which operates at 100-lb. pressure, we have a 10-in. nonreturn valve, such as shown in sketch. When we are operating our 75-hp. vertical engine and generator under light load everything works all right but as soon as we double this load and add two 25-hp. fan engines and put live steam in the heating system of the building, the valve commences to chatter and knock continuously.

Until a year ago no trouble was experienced with this valve since its installation in 1914. I have had the valve apart and all of the parts appear to be in good condition. What causes the chattering? F. G. T.



AFTER LONG USE, CONSEQUENT WEAR OF PISTON AND CHAMBER MAY CAUSE VALVE TO CHATTER

A. As this valve has been in service for 16 yr. the piston and chamber are no doubt worn sufficiently that they no longer cushion the main valve and therefore it chatters against its seat. It may be possible, however, that there is considerable pulsation from the units in your installation which has resulted in undue wear to the piston and chamber. This valve may, therefore, require a special snap ring piston on this account. The snap ring would maintain tightness against leakage even if there were a small amount of wear and it would set up a slight dampening effect which would counteract the pulsations.

Overspeed in Steam Turbines

WHAT IS THE greatest danger in connection with operation of a steam turbine and what part of the turbine requires close attention to avoid this danger? B. N. M.

A. Greatest danger in turbine operation is in overspeeding. This may be avoided by attention to the emergency trip to see that it will function correctly in case of emergency.

COAL CAN be purchased under specification as to chemical content and coal analysis used to determine whether or not the specified quality has been delivered.

Editorial Comment

A Challenge to the Power Industry

Great as the achievements of public utility engineers have been, they must not be considered by any means the best that can be done. Despite a gradual reduction in generating plant costs of about 12 per cent between 1922 and 1929, the total system costs per kilowatt of capacity have increased about 20 per cent in the same period. This is the challenge that the public utility engineer must answer in the immediate future, for it is to him that the non-technical part of the industry looks for the answer.

These facts were brought out by A. H. Kehoe in an interesting paper before the Engineering National Section of the N. E. L. A. at its annual convention in San Francisco. Remembering the slogan expressed by the Engineering National Section for some years of "More system capacity per dollar of investment," the figures presented are of great interest.

There is no need for pessimism, however, according to Mr. Kehoe, as many other factors have contributed to improvements in service to the public. On the basis of system costs per kilowatt-hour sold, there has been a reduction in investment costs from 15 cents in 1926 to 14 cents in 1929.

The challenge to the engineers lies in the fact that practically all this reduction in investment per kilowatt hour sold (occurring during a period of rising investment cost per kilowatt capacity) has occurred in power plants and in certain miscellaneous items such as service buildings, offices, and so on.

"None of it," says Mr. Kehoe, "is found in transmission, substations or distribution. These last three items have maintained substantially the same investment per kilowatt hour sold for the past four years.

"To the above improvements should be added the yearly reductions in both production costs and other operating charges to obtain the optimistic view of our system cost trends. Operating expenses per kilowatt-hour sold were reduced 18 per cent in the period between 1922 and 1928. The relative influence of the various factors which contributed to these results cannot be accurately estimated with the exception of economy of fuel consumption in steam generating stations. Such steam stations comprise over 70 per cent of our total power station capacity and they produce over 60 per cent of the total kilowatt hours. As an index of the gains made, the amount of coal required to produce a kilowatt-hour was lowered from 2.49 lb. in 1922 to 1.76 lb. in 1928, a reduction of 29 per cent. Having fewer power plants in operation has lowered operating expense. To indicate this trend it should be noted that there was a reduction of 10 per cent in this total in the last three years."

In short, while the situation is not at all critical, the facts indicate that the skill of the engineering section of the industry, applied with such notable results to generating equipment, will have to be applied now to transmission and distribution. Developments in the latter fields may come in many ways, such as introduction of new types of utilization equipment, increasing of loads, reduction of distribution losses and so on. These are the factors that offer a challenge to the highest technical skill that the industry possesses. That the challenge will be answered in many interesting and forceful ways we have no doubt whatever.

Standardization of Gages

Of the standardization work now under way, none will be of more interest or everyday value to the average power plant engineer than the work recently undertaken by the American Standards Association for pressure and vacuum gages.

Manufacturers and users will be represented on a technical committee, which will draw up standards for the following: nomenclature and definitions; rules and specifications for installation and use; method of testing; method of expressing allowable errors; accuracy requirements; capacity ratings; connections; indicator hands and stop pins; dials and graduations; bezel rings and attachments; case sizes and mounting holes.

In addition to reducing the numbers and sizes of gages manufactured and kept in stock by dealers and ultimately used in plants, the standards should do a great deal to promote proper gage installation and upkeep.

As in the case of many other instruments, gage readings obtained at present in many plants are not reliable because of improper installation or adjustment. This is particularly true of pressure gages which are often installed in such a way that a considerable head of water collects in the piping and gives erroneous readings. Ofttimes steam gages are installed without proper syphons to protect the bourdon tubes, resulting in distorted tubes and errors.

These mistakes are not wilful. They result from a lack of knowledge of those trusted with the seemingly unimportant task of installing simple gages. A comprehensive code put out by a national society will receive more attention and publicity than instructions sent out by the manufacturer and should do much to increase the dependability of instrument readings used to measure power plant performance.

Skill in Operating Power Plants

To qualify as chief engineer of a power plant a generation ago one of the first requirements was the skill of a machinist and many of our best industrial power engineers of today have come up through this route. The hand firing of boilers, setting of engine and pump valves, synchronizing of generators, alinement of belt driven equipment, repair work and mechanical adjustments are tasks that require manual skill as well

as a knowledge of the construction and operation of equipment. Because of the breadth of the knowledge and skill required, the piece-work machinist, the one-piece man, the routine artisan who must combine speed and skill has not been attracted to the power plant.

During recent years, the need for manual skill in operation has been reduced gradually by the installation of automatic devices until the need for a machinist has been narrowed practically to certain types of repair work. The man in charge of a power plant must combine the qualifications of a general machinist with those of a laboratory and executive type of technical engineer, skilled in observing conditions, adjusting equipment to effect desired changes, calculating effects of proposed alterations in equipment or heat cycle, meeting emergencies at times of accidents or unusual load conditions, keen in recognizing preventable losses with sufficient executive ability to secure and maintain the loyalty and coöperation of his assistants, with tact, diplomacy and sound reasoning ability sufficient to secure appropriations for improvements in his plant.

Managers of industrial plants are beginning to recognize that power engineers are developing into the technical executive class and are placing them in positions on a par with superintendents of other production departments, charging them with the responsibility of giving satisfactory services to the factory at the lowest possible cost, regardless of whether the power and heat is supplied from their own plant or purchased from utilities. This recognition has long been sought by the leading power plant engineers and its progress among industries will depend almost wholly upon the ability of engineers now in power plants to master the broader field.

To the Communication Industry

As this issue goes to press there are in progress two great meetings of interest to engineers the world over. One of these, the Second World Power Conference, is being held in Berlin, Germany; the other, the 53rd Convention of the National Electric Light Association at San Francisco, California. Though these meetings are being held 7500 miles apart the purposes to which they are dedicated are similar—both are concerned with the economical generation and utilization of power for the benefit of mankind, the one specifically with the power needs of the United States, the other with those of the entire world.

To attend these meetings is the privilege of only a comparatively small number of those actually interested in the proceedings. We cannot all leave our respective tasks and journey to Europe or even across the continent. It is so with us. Technical publications must make their appearance on their prescribed dates of publication and for this reason, instead of being at San Francisco or Berlin this afternoon, we find ourselves writing this editorial in Chicago.

We live in a marvelous age, however, and though we write these words in Chicago, it has been our privilege this afternoon to attend both of these meetings at the same time. Not only did we hear speakers at San Francisco, London and Berlin, but at one time upon the conclusion of an address by Dr. Oskar von Miller at Berlin, we distinctly heard the applause of the audience in the auditorium at San Francisco over seven thousand miles away! At one moment we heard the voice of Senator Marconi speaking from London; an instant later, that of Owen D. Young at San Francisco, and still a few moments later, comments upon both of these addresses from a speaker at Berlin.

It is not our purpose here to describe all the details of this marvelous program, but to direct attention and to offer tribute to the work of the communication engineer in making this feat possible. Our own industry, the electric light and power industry, has to its credit as enviable a record of progress and human achievement as could be desired and yet beside the achievements in the art of communications it must take second place. This is not our own opinion, but that of one of America's greatest business statesmen, Owen D. Young, Chairman of the Board of the General Electric Co. Testifying before a United States Senate Committee on Communications recently, Mr. Young paid tribute to the communication art which may well be recorded here. These were his words:

"One may call almost anybody in this northern hemisphere or in the principal countries of Europe and carry on a conversation provided he can understand. It is language, not facilities, which is the barrier to such communications. When one thinks of the convenience, speed, and vast distances over which communication by voice may be carried on, specially in this country, one must accept it as among the greatest, and perhaps *the greatest*, of human achievements of a great age. It is no mere chance that the American Telephone and Telegraph Co. is the largest concern in the United States, both in investment, in stockholders and, I believe, in employees.

"It is a reflection of public response to the service. I pay this tribute, gentlemen, to the American Telephone and Telegraph Co., not because I have any interest in it, direct or indirect—nor have any of the companies with which I am associated. As a matter of fact, the General Electric and Westinghouse companies feel that in power and light they have made great developments. They would wish to stand first, and perhaps claim that position in the service of the people. I say what I do about telephony under these circumstances because I am talking about communications and because I wish to acknowledge publicly the great service which has been rendered."

The bringing together, by means of wire and radio circuits, of the World Power Conference and the N. E. L. A. Convention on June 18 bears evidence as to the correctness of Mr. Young's statement. Over a circuit, stretching three thousand miles across the American continent, bridging the Atlantic and passing underneath the English Channel to the land lines of Germany, the speakers at both meetings talked as though they were in the same room. And as they talked the world listened in. In addition to being broadcast over the National Broadcasting Co. networks in America and the English and German networks in Europe, the program was also sent by short wave radio from WGY and KDKA to Japan and Australia so that practically anybody in the world with a receiving set could hear.

Surely, if this is not magic, nothing is.

Semi-Annual Meeting of the A.S.M.E.

SEVERAL SESSIONS AT DETROIT MEETING
INTEREST ENGINEERS OF POWER PLANTS

UNUSUAL hospitality greeted the visiting engineers at the Semi-Annual Meeting of the American Society of Mechanical Engineers, held in Detroit, June 9 to 12. Nearly 600 registered during the meeting, the general plan being the holding of technical and business sessions during the morning, with inspection trips to the various factories in the afternoon and entertainment in the evening provided by the local committee.

Among the social events of the meeting were the smoker given for the men, the entertainment features being numbers from current programs at Detroit theaters, and on Wednesday afternoon and evening the Steamer Eastern States was chartered for a Detroit River and Lake St. Clair boat trip. All visiting engineers were greatly pleased with the arrangement of the program and entertainment provided by the local committee.

Nominations for officers of the Society for 1931 were announced, election will be by letter ballot of the entire membership, closing September 23, 1930. The nominees, as presented are: President, Roy V. Wright, Managing Editor, Railway Age, New York, N. Y.; Vice-Presidents, William A. Hanley, Thomas R. Weymouth and Harvey N. Davis; Managers, W. L. Batt, H. L. Doolittle and H. L. Whittemore; Representatives to the American Engineering Council, W. R. Webster, R. V. Wright, J. W. Roe, Robert Yarnall, E. N. Trump, B. E. Hull, E. O. Eastwood, W. Trinks, Warner Seely and William S. Conant.

PROPERTIES OF METALS

Considerable attention is now being given in both this country and Europe to "creep" tests (or flow tests) in which the time-deformation relationship is determined for metals subjected to constant loads for long periods at approximately constant temperatures. The paper presented by H. J. French, Wm. Kahlbaum and A. A. Peterson dealt with this subject under the title "Flow Characteristics of Special Fe-Ni-Cr Alloys and Some Steels at Elevated Temperatures." The authors stated that previous tests at the Bureau of Standards have related jointly to the development of a testing technique and to the procurement of data intended to assist engineers in the selection of safe working stresses for equipment designed to operate at elevated temperatures.

The work in this paper simply represents the extension to more materials of the methods of test which have already been described in detail in Technologic Papers of the Bureau of Standards.

In a paper entitled "Flow Characteristics of Some Lead Cable Sheath at Temperatures Above Atmospheric," C. L. Clark and C. Upthegrove gave results of investigation on three types of lead cable sheath differing only in the antimony content which was respectively 0.06, 0.6 and 1.2 per cent.

"An Apparatus for the Determination of Creep at Elevated Temperatures," was the title of a paper by A. E. White, C. L. Clark and L. Thomassen which described an apparatus designed for the purpose of measuring creep of metals at elevated temperatures. Due to the slight changes in dimensions encountered, such an apparatus must be sensitive to small variations. This particular machine is stated to be capable of measuring variations in length of the test specimen to about 2.8 millionths of an inch per inch.

It is stated that the temperature fluctuations, even though of the order of plus or minus 2 deg. C., are sufficient to cause a noticeable rotation of the mirrors employed on this apparatus.

THE BOILER FEEDWATER STUDIES

Appreciating that operators of boiler plants recognize the necessity of excluding any contamination from the steam and water cycle in steam power plants, Max Hecht and D. S. McKinney presented a paper entitled "Electrical-Conductance Measurements of Water and Steam, and Applications in Steam Plants" in which a conductance method is presented for determining the concentration of salts in steam-plant water supplies. The method is applied to determine the purity of steam, of supplies used for boiler-feed purposes and the concentration of boiler and evaporator water.

In the opinion of the authors, the conductance method has been successfully applied to boiler room problems for observing entrainment in steam and concentration of salts in steam-generating vessels.

"Fractures in Boiler Metal" was the title of a paper presented by A. E. White and R. Schneidewind which was developed from a study of the causes of failures in boiler materials. The authors divided these roughly into three general headings: defects due to the composition of steel or to steel mill practice, defects due to methods of boiler construction and defects developing as a result of conditions of operation of the equipment.

It was stated that high sulphur and especially high phosphorus contents in steel had been mentioned as contributing causes of brittleness. Others believe that the combined contents of phosphorus and arsenic determined to a large extent the satisfactoriness of boiler steel.

Segregation of constituents and other non-homogeneities such as are revealed by microscopic etching are commonly found near fractures. In many cases, however, segregations do not constitute serious difficulty. Pipes, blow holes, seams and inclusions constitute defects of a serious nature. Many failures have been traced to serious strains induced by careless riveting in the process of constructing the boiler.

Considering the data regarding the performance of welded joints in resisting repeated stresses as extremely important in any consideration of the adoption of welded construction for power boilers, H. F. Moore has conducted a series of investigations and presented at this

meeting a paper entitled "Tests of the Resistance to Repeated Pressure of Forged, Riveted and Welded Boiler Shells" in which the results of his work were recorded.

As a result of his investigations, the author concludes that the tests indicate that properly made welded joints have greater resistance to repeated stress than the plates themselves and when weakened by rather small surface defects or by tapped holes. The results obtained on one arc-welded shell indicate that a stress raiser such as a hole is particularly dangerous when located in the welded joint. The tests also show that wide variations in fatigue strength will result from different types of welding. The necessity for the development of a good welding technique is obvious. The necessity for a rigid system of inspection of the finished welded vessel is also obvious.

"Boiler Settings for Burning Refuse Wood" was the title of a paper presented by C. S. Gladden which was a discussion of some recent developments in the design of boiler furnaces for burning green or wet refuse wood, the experiences influencing the developments of furnaces for burning dry refuse wood and the factors influencing the design of wood burning furnaces.

He illustrated, with drawings, designs for the successful burning of wet-wood refuse, for air-dried and kiln-dried wood and cited the development of a successful furnace and boiler setting for burning dry wood refuse in the General Motors Corporation's plant at St. Louis.

Fuels and Power

Wm. O. Renkin, in a paper entitled "The Dry Quenching of Coke," described the process of dry quenching or cooling of coke with automatically formed inert gases, the sensible heat in the glowing coke being used to heat cooling gases which in turn pass through boilers producing steam at useful pressure and economic cost without the consumption of any other fuel. Formulas, curves and data regarding heat available and method of calculation were given, together with descriptions of installations and illustrations of plants in operation.

In checking the solution to the fly ash problem in a plant of the Consumers Power Co., J. W. MacKenzie made investigations, the results of which he presented in a paper entitled "Recovery of Fly Ash from Pulverized Fuel Stacks by Use of Stack Sprays." The extent of the trouble was determined by locating boards freshly painted with white paint throughout the district. A water spray installed in the stack stopped all complaints but necessitated lining the stack with acid resisting material.

The tests show that with the spray in operation about 5 per cent of the coal is discharged as solids from the stack and that the spray takes out about 35 per cent of the solids coming to the stack.

In the Long Beach station of the Southern California Edison Co. between June and November of 1929 a series of tests were conducted in order to obtain performance data showing the operating characteristics of a large burning oil and natural gas fuels. F. G. Philo presented a paper describing the tests and drawing conclusions under the title "Comparative Performance of a Large Boiler Using Oil and Natural Gas Fuels."

The boiler tested was a Babcock & Wilcox cross drum, straight tube type with interdeck superheater and water cooled walls. Peabody combination oil and gas burners were used. The highest rate of output at which the boiler was tested was 450,751 lb. of steam per hr., which represented operation of the 3416-hp. boiler at 413.2 per cent of rating. Efficiency capacity characteristics are straight lines between 100 per cent and 400 per cent rating. Efficiency with oil fuel is approximately 4 per cent higher than with gas due to higher hydrogen losses with gas fuel. Superheated steam temperatures are considerably higher when burning gas than when burning oil fuel, due jointly to lower water-wall heat absorption and larger flue-gas volume while burning gas fuel. Maximum heat liberation was 27,300 B.t.u. per cu.ft. of furnace volume, although it is felt heat-liberation rates as high as 60,000 B.t.u. per cu. ft. might be satisfactorily maintained in this furnace.

As a result of an experimental program which had for its objective the comparative performance of a modern boiler unit served first with a bin system of pulverized coal firing and later with a unit system of firing, thus making possible comparisons on a common basis. A. E. Grunert presented a paper entitled "Comparative Performance of a Pulverized Coal Fired Boiler Using Bin System and Unit System of Firing." In this paper were given the specific types of equipment, certain types of coal and operating conditions which were influenced somewhat by local conditions.

The operation of these two systems was compared in three ways: first, on an evaporative test basis; second, on a basis of actual overall performance; and third, on an operating cost basis. A record of the pertinent experiences with both systems was given. Owing to the specific nature of the program, no general conclusions were given.

It was stated that it is not likely that any data could ever be prepared which would conclusively prove the superiority of one method over the other. That each will eventually find its own field and profitable application seems a permissible prophecy in view of similar situations in the past.

It would be perfectly natural to compare the present final results of these two systems to other methods of combustion at this same station using the same unit basis.

They are given in the following table:

	18 stokers	No. 22, bin system	No. 22, unit system	Another type, unit system
Period covered	93 mos.	24 mos.	11 mos.	26 mos.
Total cost in dollars per 1,000,000 B.t.u. delivered, with a coal cost of $18 per 1,000,000 B.t.u.....	0.26847*a*	0.25374*b*	0.26258*b*	0.26216
Evaporative efficiency, per cent...	77.4	83.85	83.7	81.1*c*
Auxiliary power, kw-hr. per ton..	13.56	55.33	51.31	54.41

*a*Unusual expenses incurred by outages, maintenance, and renewal of all eccnomizers included.
*b*Unusual expenses cited in Table 10 included.
*c*Records of the last few months indicate that rehabilitations have improved performance.

In the presentation of this paper an attempt was made to record only the facts as they were and in this particular case for what they may be worth to the increasing store of information on these matters. It was borne in mind that a precise critical analysis of the two methods of firing may as yet be premature in view of the many complications of the situation and developments at present in progress.

Power Plant Engineering Developments and News

Remote Control System

By R. D. Bean*

REMOTE CONTROL device has been developed, designed to use self-synchronizing alternating current motors which have the property of remaining accurately in phase. When connected and energized, any power applied to one motor will be transmitted to the other with comparatively little distortion and their action can not only be used to transmit indications but also to transmit power necessary to effect control. Use of such mechanism, it is claimed, not only permits great ease and simplicity in control from a central point but also permits great latitude in the design of piping and equipment. Control of valves can be effected without respect to their position in the system, it is stated.

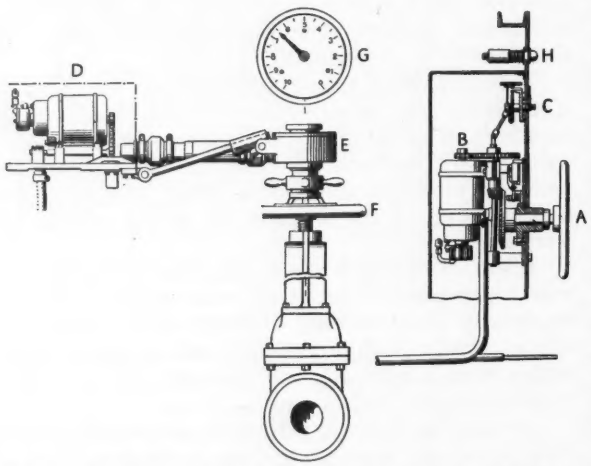


FIG. 1. SCHEMATIC DIAGRAM OF DE FLOREZ CONTROL SYSTEM

The motors, known as Selsyn Motors, are a product of the General Electric Co. The motors, which are entirely encased, are further gas proofed by suitable covers and the rotating shaft, mounted on ball bearings, is intended to make possible their use in any position. They are made in three sizes depending on the power required and whether the units are required for transmission of power or indicating mechanism.

Arrangement of a transmitting and receiving mechanism as applied to a valve is illustrated in Fig. 1. The transmitting mechanism comprises a wheel which rotates the transmitting motor through a gearing and through which the control is effected. The rotating of the transmitting motor causes the rotation of the receiving motor, the motion of which is transmitted through gearing to a shaft and thence to a worm gear which in turn is connected to a wheel on the valve stem. The worm gear mechanism is connected to the valve wheel by a clutch, half of which is clamped permanently to the spokes of the valve wheel, the other half being directly connected with the worm mechanism. A quick detachable clutch is inserted between the wheel and the worm case so that the mechanism can be disconnected quickly and at will. Drive shaft from the receiving motor is flexible so that the mechanism can be applied to a wheel which is solidly mounted on the valve stem and which will rise and fall as the setting is changed. In addition to this, the worm gear is hollow so that, if the mechanism is applied to a rising stem valve, the stem can pass freely through the center of the worm.

The transmitting unit is made up in small panels roughly 30 in. by 16 in. to be bolted through control panels or assembled in batteries. A pointer or indicator is connected with the motion of the transmitter wheel to denote the amount the system is turned and a pilot light is incorporated in the unit to indicate when the circuits are energized.

The receiving mechanism is designed to be applied to any type of valve or to effect any rotary motion desired. The power transmitted to the receiving mechanism is stated to be only that which is impressed on the transmitting wheel. Thus the resistance to motion can be gaged, it is claimed, and the actual amount of correction observed on the wheel in the same manner as it would be observed in turning the valve itself. There is, of course, some loss in friction but this is comparatively small and ample power is provided to

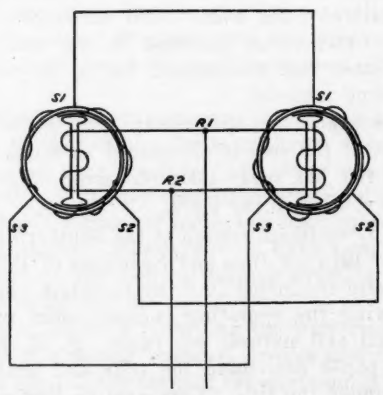


FIG. 2. DIAGRAM SHOWING OPERATING PRINCIPLE OF SELSYN MOTORS, THE BASIS OF THE CONTROL SYSTEM

*Manager of Engineering Development, The Brown Instrument Co., Philadelphia, Pa.

start the valve from full closed jammed position when necessary.

Power is transmitted at low torque and high speed and the extent to which the motors are out of phase becomes relatively unimportant, since this amount, which may aggregate 5 or 10 deg., is reduced in proportion to the gear ratio. The mechanisms are made usually to transmit from 150 to 200 ft. lb., which appears to be ample to turn any valve mechanism. They also can be made to operate in any ratio desired to obtain close control and it would be possible to have, by changing the gear ratio, four turns of the transmitting wheel to one turn of the valve if close regulation is desired or a heavy valve is to be turned.

The mechanism is safeguarded by the fact that the motors do not rotate when energized by the current and respond only to hand motion. If the current should fail, the valve would remain in whatever setting it happens to be placed; but, as noted previously, it is designed to be operated by hand and released from the control system if necessary. There is no danger of overloading or of breakage, it is claimed, since the power transmitted is merely that applied to the transmitting wheel. Any resistance or reaction on the receiving end is of course felt on the transmitter, so that, if the valve were jammed or its stuffing box too tight, this resistance would be felt in transmitting the motion. In other words, the man operating the Remote Control can actually feel what he is doing and obtain an immediate and natural reaction to any adjustment he makes.

The mechanisms were originally constructed to take care of special conditions in the design of petroleum refining units but in view of their apparent general usefulness, provision has been made to make the device available for other uses. The Brown Instrument Co., Philadelphia, Pa., has undertaken the construction and sale of this equipment.

Engine for Burning Distillate

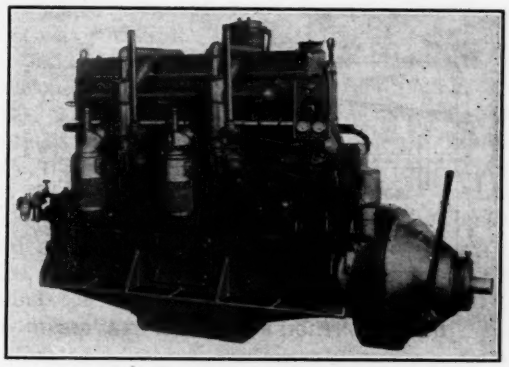
APPLICATION of equipment for the burning of distillate in its new Blue Streak engines is announced by the Climax Engineering Co., of Clinton, Iowa. These models are produced in five sizes, varying from 70 to 200 hp. The outstanding feature of this oil burning equipment is its design for high power and economy on cheaper fuel, to give about the same performance as gasoline on the average engine of the same displacement.

All cylinders on these engines are made of chrome nickel iron. The bore and stroke are 5½ by 6½, 5¾ by 6½, and 6 by 7 in. in the four-cylinder models and 6 by 7 in. in the six and eight-cylinder models.

Heads of all of these engines are cast in pairs and are made detachable. They are made of chrome nickel iron with a high Brinell to insure long life.

Crankshafts are drop forged, heat treated and alloy steel in the larger sizes. Main bearings are babbited and bronze backed and are of ample size and number to insure long life and ability to stand heavy duty. The valves are in the head of the motor and fully enclosed. The intake is of nickel steel and the exhaust is made of silichrome.

Lubrication is at pressure of about 20 lb. to all bearings and overhead valve rockershaft bearings. The



BLUE STREAK 135-HP. ENGINE WITH SPECIAL EQUIPMENT FOR BURNING DISTILLATE SIZES RANGE FROM 70 TO 200 HP.

pump is of the eccentric vane type. A centrifugal pump with shrouded impeller furnishes water circulation. In conjunction with the special Zenith carburetors used on these engines, the intake manifold is jacketed.

A special device also is added, consisting of a heat control of the primary air and water injection.

To permit higher power output and higher compression heads, water is injected into the intake manifold for throttle positions greater than ¾ openings. This is controlled automatically. This water is pumped by an A-C fuel pump handling water instead of fuel at pressures of three to four pounds.

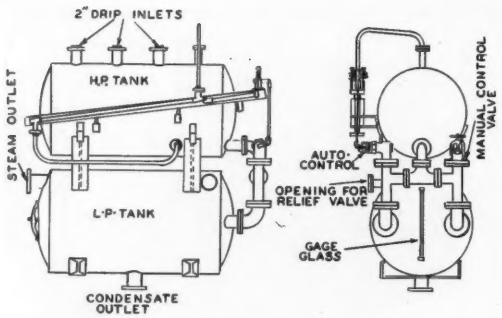
Drain Control for Steam Lines

TO INSURE continuous and automatic draining from high-pressure steam lines and to eliminate the use of numerous traps, the Elliott drain control has recently been devised. It is designed to be entirely automatic in operation and to have no moving parts except for a thermostatically controlled valve.

The unit consists of a high-pressure receiver and a low-pressure receiver with two control valves interposed between them. One valve is manually controlled; the other is controlled by a thermostat on the side of the high-pressure receiver. Condensate is collected in the high-pressure receiver, expanded to a lower pressure through the special control valves and collected in the low pressure receiver, whence it is pumped or discharged at some convenient point.

The receiving tank is of hammer-weld steel pipe, with bumped heads, the shell lapped over the heads and welded. Hammerweld forged tanks can be furnished. Multiple drip inlets are furnished, together with two-valve controlled outlets.

Special expansion valves, between receivers, as noted above, allow the condensate to expand from higher to lower pressure. These valves are built with a number of expansion orifices and chambers. The pressure reduction at each orifice is proportional to the number of orifices, so that the pressure drop across the valve and seat is small. The manually-controlled valve is set to take care of minimum flow, the fluctuations passing through a similar valve thermostatically controlled. The thermostat is located so that when condensate rises above the center line of the receiver, the auxiliary valve will



DRAIN CONTROL FOR 600-LB. SERVICE

open. The thermostat is a bimetallic, expansion positive tripper type. The low pressure receiver is of the same general construction as the other except that the shell is of monoweld pipe.

This drain control is made by Elliott Co., Jeannette, Pa. for three pressure standards of 250, 400 and 600 lb.

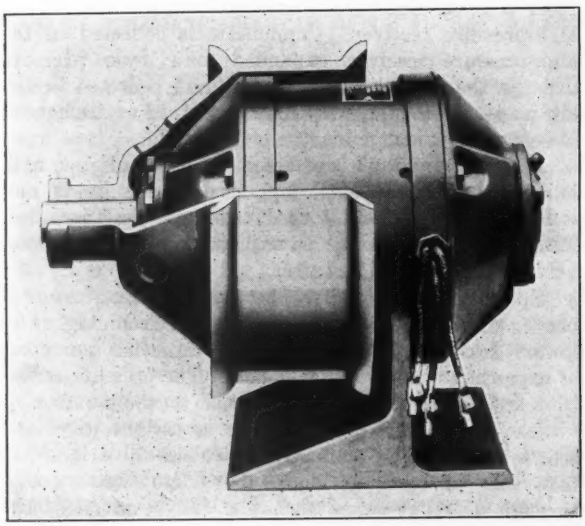
Special Motors for Runout Tables and Conveyors

SPECIAL MOTORS, designated Type M, for runout tables in steel and tube mills and for other conveyor work have been developed and built by the Reliance Electric & Engineering Co., Cleveland, Ohio.

These motors are each provided with a single heavy welded-steel support located so that a pulley-type roller keyed to the motor shaft can rotate around the body of the motor. Various shaped rollers to suit the material to be conveyed can be used.

The motors with rollers are lined up in tandem, the distance between being governed by the material conveyed. An installation may require any number of units depending on the distance of travel and the roller spacing.

The motors are fully enclosed to protect them from all injurious elements. They are provided with class B insulation; i.e., asbestos and mica designed to withstand extremely high temperatures. Large ball bearings are used to carry the motor-rotor and load with an ample margin of safety.

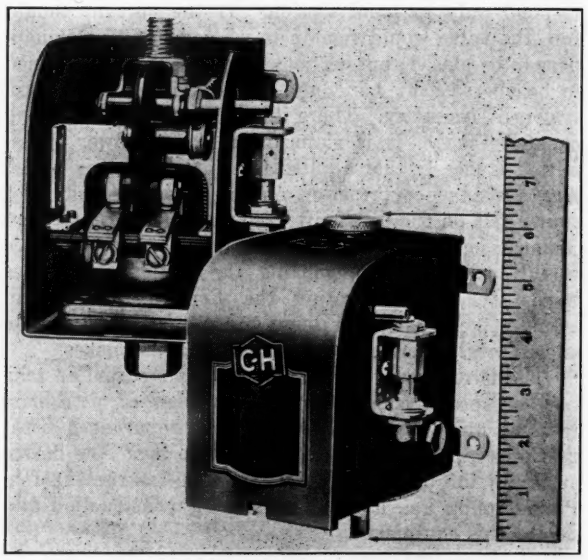


PULLEY TYPE ROLLER REVOLVES ABOUT BODY OF MOTOR

Small Limit Switch

SINGLE-POLE limit switch for general service is announced by Cutler-Hammer, Inc., 191 12th St., Milwaukee, Wis. It is designed to be a small, exceptionally sturdy device, to be applied on machine tools, conveyors, dough mixers, wash machines and other small equipment, to start, stop or reverse the motor at its limits of travel.

Two types are furnished; one with normally closed contacts which are opened when the operating roller is depressed and the other with normally open contacts which are closed when the roller is depressed.



SINGLE-POLE LIMIT SWITCH

Double-break contacts with silver-rivet contact tips are used to reduce pitting and insure long life. The movable contact is connected to the machined steel operating roller through a sliding shaft and a heavy bakelite strip. A knockout hole in the end of the cast-bronze enclosing case and accessible screw terminals facilitate wiring.

High-Pressure Gage Glass

TO GIVE complete protection from the delays and dangers of broken water glasses, the new Diamond high-pressure gage glass and water column has been developed by the Diamond Power Specialty Corp., Detroit, Michigan, featuring Loose Window construction.

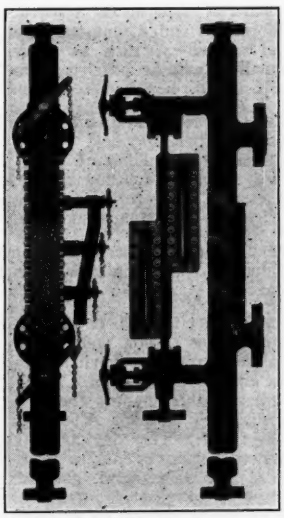
Gage glasses are subjected, it is stated, to solvent action of boiler water at high pressure and temperature and to strains set up in the glass due to the effort to keep the glass tightly packed against the high pressures.

For high pressures it was found that tightening the gage body directly against the glass to produce a water and steam tight joint set up such strains that flat

glasses would crack, sometimes even before they were put in service.

The Diamond high-pressure gage glass was developed to overcome this disadvantage and to incorporate other improvements. In the Diamond construction, the clamping of the window glass is avoided. A clear sheet of mica is clamped under each window frame to form a diaphram or drum-head. The window glass is virtually loose, being cushioned against the mica and supporting it.

This construction is designed to leave the glass entirely free from clamping strains and protected from damage that might otherwise result from expansion and contraction. As a consequence, longer windows, affording greater length of vision, are obtainable. The glass



VIEWS OF NEW HIGH-PRESSURE GAGE GLASS

is not intended to be subjected to higher pressure than the steam pressure itself.

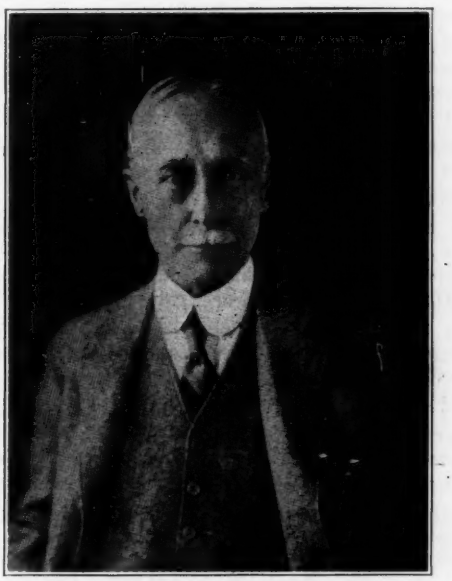
Diamond gage valve bodies are forged steel; seats are renewable and made of heat treated stainless steel. Self aligning valve discs are of monel metal, valve stems are of the same metal and special threads, external to the valve body, are provided to assure quick opening. Design of valves provides for quick renewal of any part. Diamond gage cocks have renewable seats, discs and stems and follow the same general design as is used in the gage valves.

Death of Elmer A. Sperry

ELMER AMBROSE SPERRY died on June 16 at St. John's Hospital, Brooklyn, New York, where he had been confined by illness for nearly ten weeks. Mr. Sperry was born in 1860 in Connecticut, attended the State Normal School and Cornell University and during his 21st year began the manufacture of arc lamps, dynamos, motors and electrical equipment by his own company, the Sperry Electric Co. of Chicago. He had already begun his inventions with a new method for arc lamp control and he continued his inventions in this field for many years, developing various types of arc lamps, some of great intensity, together with methods of control.

Besides his work with the arc lamp, Mr. Sperry developed electrical machinery for mining, electric street cars and equipment, electric motor cars, unproved methods of caustic soda and electric battery manufacture, torpedo control and propulsion.

The general public knows Mr. Sperry best for his work with the gyroscope. Starting with an apparatus that had been only a toy, he developed the gyro compass, now standard equipment on naval vessels and the foundation of naval gunnery control; the ship stabilizer for preventing roll; control for aircraft by stabilization



ELMER A. SPERRY

and draft indication. A total of 400 patents stand to his credit for his various inventions.

Mr. Sperry was president of the Sperry Gyroscope Co., Brooklyn, N. Y. In December, 1928, he was elected president of the American Society of Mechanical Engineers. He had been awarded several decorations by foreign governments for his technical achievements. He was awarded the Franklin Medal, Collier trophies, Aero Club of France Prize and many others for his inventions. He was a member of the A.I.E.E., Am. Chem. Soc., Physical Society, Soc. Naval Architects and Marine Engrs. and other technical and social organizations.

Nonresonating Transformers for California

THREE 40,000-kv-a., 220,000-v. transformers of the new nonresonating type developed by the General Electric Co. have been installed at the Long Beach No. 3 generating station of the Southern California Edison Co. The nonresonating feature permits higher factors of safety than have ever been reached heretofore. Electrical stresses throughout the entire winding are reduced, even under the most severe lightning conditions.

The insulation of these transformers is coördinated with that of the rest of the transmission system; that is,

the transformers are designed to be electrically stronger than the insulators that carry the 220,000-v. transmission line. Thus, if lightning should strike the line or very high voltage surges should be induced in the line by a nearby stroke, the line insulators will be the first to flash over and thus tend to relieve the abnormal voltage stress.

Being located near the ocean, these transformers are subjected to salt fog which leaves conducting deposits on the high voltage bushings. The bushings are therefore specially designed to give an extra long creepage distance between live parts and the tank, so that they can be washed periodically with a spray of water without removing the transformers from service. Because of the unusual design, the bushing is supplied with an arcing horn to form a gap by which the normal dry flashover value of the bushing is maintained.

Each transformer occupies a floor space of about 18 by 20 ft. The height over the cover is nearly 18 ft. and over the high voltage bushings is 28 ft. The total weight, including 14,000 gal. of oil, is about 136 t.; without oil, it is 84 t.

In spite of their size, no appreciably greater difficulties were involved in their transportation and installation than if they had been rated 10,000 instead of 40,000 kv-a. They were shipped from Pittsfield, Mass., to Los Angeles in 13 days, each assembled in its own tank and loaded on a standard transformer car. They were made ready for installation on arrival by merely refilling the transformer with oil and reassembling certain parts which were removed prior to shipment to meet railroad clearances. Each tank was filled with nitrogen gas during shipment to exclude air and moisture.

News Notes

ELLIOTT CO. and associated companies, The Lagonda Mfg. Co. and Liberty Mfg. Co., announce a change in address of their Chicago district office from 1129 Conway Building to 1534 Twenty North Wacker Drive, Chicago, Ill.

PEABODY ENGINEERING CORP., 40 East 41st St., New York, announces after May 1, 1930 the address of the Los Angeles District Office will be 912 East Third St., Los Angeles, Calif.

BLAW-KNOX CO., Pittsburgh, Pa., announces that William E. Balliet succeeds P. V. Kelly as manager of the Birmingham office of the company in the Brown-Marx Building, Birmingham, Ala. Joseph Riley will become assistant manager of the district.

GUISEPPE FACCIOLI, electrical engineer, has retired from active participation in the affairs of the General Electric Co. because of ill health. Mr. Faccioli has relinquished his duties as Pittsfield works engineer and associate manager of the Pittsfield works of the company and assumed the position of consulting engineer.

PULVERIZED FUEL EQUIPMENT CO., a division of Borg-Warner Corp., Builders Bldg., Chicago, Ill., announces the appointment of the following direct sales representatives: E. L. Sullivan, Oliver Bldg., Pittsburgh, Pa., and H. P. Rogers & Co., Leader Bldg., Cleveland, Ohio.

UNITED STATES CIVIL SERVICE COMMISSION announces open competitive examination for junior engineer, applications for which must be on file with the Civil Service Commission at Washington, D. C., not later than July 8, 1930. Entrance salary for positions in Washington, D. C., is $2,000 a year. For appointment outside of Washington, D. C., the salary will be approximately the same. Optional subjects are (1) agricultural engineering, (2) chemical engineering, (3) civil engineering, (4) mechanical engineering, (5) mining engineering, (6) naval architecture and marine engineering, and (7) structural steel and concrete engineering. Competitors will be rated on general physics, mathematics, and the optional subjects chosen from those named above. Senior students will be admitted to the examination.

Full information may be obtained from the United States Civil Service Commission, Washington, D. C., or from the Secretary of the board of examiners at the post office or customhouse in any city.

STEEL PLANT having an annual output of 1,000,000 t. is to be built in Kuznetsk, U. S. S. R. by Freyn Engineering Co., Chicago, consulting engineers. An agreement to this effect was concluded today with Novostal, Soviet Combine in charge of construction of new Russian steel works.

The new steel works, which will be known as Kuznetsky Works, will consist of four blast furnaces, twelve open hearths, blooming mills, rail and structural mills, continuous billet mills, plate mills, four batteries of coke ovens, a power plant having a capacity of 96,000 kw. and all the auxiliaries required by a modern steel plant.

The detail design of this steel works will be carried out in Moscow and Leningrad, as well as at the construction site. Freyn Engineering Co. will increase its engineering staff in the U. S. S. R. to a total of 50 to 60 men. These American engineers will design and superintend the assembly, erection and initial operation of the steel works. It is estimated that three years will be required to build this plant.

Much of the material used in the construction of Kuznetsky Works will be fabricated and manufactured in Soviet industrial plants, but special machinery, such as rolling mills, electrical equipment and the like, will be purchased in America or other foreign countries.

AT THE REGULAR QUARTERLY MEETING of the board of directors of Chicago Pneumatic Tool Co., held June 3 at the company's offices, Chicago Pneumatic Building, 6 East 44th Street, New York, W. L. Lewis, formerly assistant comptroller of Bethlehem Steel Corp., was elected vice president, secretary and treasurer, succeeding J. G. Grimshaw, secretary and treasurer, resigned.

FRANK F. FOWLE & Co. announces that its address, since Monday, June 2, is Suite 2254, La Salle-Wacker Bldg., 221 North La Salle St., Chicago.

FOUR OVERHEAD 66-kv. circuits between the transformers at its Columbia Park generating station and its terminal transmission lines are to be replaced with three-conductor cable of like capacity by the Union Gas and Electric Co. of Cincinnati. It will be the first such installation in this country and is to be used in filled ground which is subjected to submersion by flood stages of the river at certain times and to very dry conditions at other periods. The oil-filled armored cable, covered in turn with paper insulation, a lead shath, a layr of asphaltd jute, two bands steel tapes, and an outside layer of asphalted jute, is designed to be unaffected by either excessive wetness or dryness.

The cable, which is being built by the General Electric Co., will be shipped and installed in five lengths, each approximately 1300 ft. long. Four of the cables are to carry load (37,500 kv-a. each) at one time; the other cable will be a spare. Thirty-two oil-filled terminals and twelve feeding-type oil reservoirs will be used with the installation.

AMERICAN ARCH CO. announces the removal of its main offices from 17 East 42nd St. to the Lincoln Building, 60 East 42nd St., New York City.

EDGE MOOR IRON CO. announces the appointment of Harry L. Moody as general sales manager of this company, commencing June 1, 1930. Mr. Moody will be located at the main office, at Edge Moor, Delaware.

ARTHUR J. SELZER, commercial agent for the Westinghouse Electric Supply Co., died suddenly at Hot Springs, Va., while attending the convention of the National Electrical Manufacturers' Association. Mr. Selzer had been commercial agent for the Westinghouse Supply Co. during the past four years.

BROWN INSTRUMENT CO., Philadelphia, Pa., has just let a contract for 40,000 sq. ft. of additional floor space to the Robert E. Lamb Co. of Philadelphia, Pa. Mechanical and electrical equipment will be installed under separate contracts with local concerns. This extra space will be in the form of two additional floors on all of the new two-story concrete sections of the plant. The plans for the work were prepared by The Ballinger Co. of Philadelphia, Pa., under the supervision of W. E. Camp, industrial engineer of The Brown Instrument Co. Construction will be started very shortly and the new space will be occupied early this Fall.

TRUSTEES of Battelle Memorial Institute, Columbus, Ohio, announce the appointment of Floyd B. Hobart as fuel chemist. Mr. Hobart joins the staff with R. A. Sherman, fuel engineer, to work under the direction of Clyde E. Williams, assistant director. This group forms the nucleus of an organization within the Institute devoted to research problems in fuels.

Mr. Hobart comes to Battelle Memorial Institute from the Atlantic Refining Co. where he has been chemical engineer in plant experimental and standardization work.

DAVIS REGULATOR Co., Chicago, Ill., has completed a new factory building at 2541 South Washtenaw Avenue, into which all departments were moved on June 1, 1930. Simultaneous with the announcement of the new address is the change of name from G. M. Davis Regulator Co. to Davis Regulator Co.

HAROLD K. FERGUSON, president of The H. K. Ferguson Co., Cleveland, Ohio, recently announced that his company has acquired the business, assets and good will of Warren D. Spengler, Inc., of Cleveland.

The entire personnel of Warren D. Spengler, Inc., will join The H. K. Ferguson Co.

PREST-O-LITE Co., INC., 30 East 42nd St., New York, N. Y., announces the opening of a new plant at 1240 Stewart Ave. S. W., Atlanta, Ga. The old plant at 345 Kuhrt St. S. W., Atlanta, will discontinue operations.

Books and Catalogs

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS GUIDE, 1930; 8th edition, 888 pages, illustrated; flexible blue binding, 6 by 9 in.; published annually by American Society of Heating and Ventilating Engineers, 29 West 39th St., New York City; price $5.

Each year since its publication the A. S. H. & V. E. Guide has shown marked improvement in scope and usability, but this edition, the eighth, takes a much longer step forward and constitutes one of the most valuable publications in the entire engineering field.

Various phases of the subject are, of course, brought strictly up to date in accordance with the usual practice. The whole book, moreover, has been revised and rewritten so that the information in the various sections is coördinated much more closely than in previous editions. A great deal of new material has been added and the guide contains a catalog data section giving information by manufacturers designed to supplement the discussion in the body of the book. These manufacturers' data include tables of sizes, capacities and necessary information for design work and constitute a valuable supplement.

A feature of the guide is that the index is at the front of the book. A complete list of the members of the A. S. H. & V. E. is also given.

The various introductory chapters cover heat losses, ventilation, heating with various types of systems, air conditioning and cleaning unit heaters, heating by coal, gas, oil and electricity. Then come chapters on details of chimneys, boilers, radiating surfaces, heat control, piping, traps, pumps and fittings, insulation, fans and air ducts. Final chapters deal with pneumatic exhaust systems, drying ozone and special heating and ventilation applications.

The chapter on drying by evaporation is especially interesting as it incorporates many new data. A chapter is devoted to a summary of important specific items providing a suggested list for checking in writing specifications. Pneumatic exhaust systems are well covered.

There is a great deal of new and interesting material in the chapter on conductors and convectors for heating by steam and hot water. Piping and equipment for laundry, kitchen and hospital service is given considerable attention, as is water supply piping for buildings.

The other chapters have been revised and coördinated as noted above. The latest edition of the guide should by all means be in the hands of every engineer who has heating and ventilating problems.

HEAT LOSS ANALYSIS, by E. A. Vehling; 241 pages, cloth, 6 by 9 in.; McGraw-Hill Book Co., Inc., 370 Seventh Ave., New York; price, $2.50.

In this book, simple formulas have been developed for calculating and analyzing heat losses, based on the demonstration that the heating value of an amount of coal containing a pound of carbon is the same, within practical limits, for all coals of the same type.

The book is intended for the operating personnel of the boiler house, to give them a clear understanding of the processes of combustion and heat absorption and to serve the operating engineer in converting his recorded data into corresponding heat losses.

Theory of combustion and heat absorption are first discussed, followed by an explanation of the equicalorific fuel unit and demonstration of the use of pound-carbon fuel unit. Then follow chapters in which the formulas are developed, analysis of factors causing heat loss analysis of heat losses, economic relation between CO and CO_2. Operating efficiency by the analytical method is treated and the book concludes with chapters on applying this method to control of boiler operation, on the bonus system, and on methods of controlling boiler operation.

G-E VITREOUS-ENAMELED RESISTORS are described in catalog GEA-1238 by General Electric Co., Schenectady, N. Y. CR3100 drum controllers for series, shunt, or compound-wound direct-current motors are described in bulletin GEA-973A. General Purpose synchronous motors, "7500 Series" are described in bulletin GEA-246B. CR9440-LS415 Hatchway Limit Switch for control circuits is described in bulletin GEA-1252. Farbroil gears price list, is given in bulletin GEA-1043A. Nonmetallic Gears & Blanks price list is given in bulletin GEA-818A. Synchronous Converters for mining service, Type HCC, are described in bulletin GEA-1270.

LINE CONTACTS for group-operated outdoor disconnecting switches are described in bulletin GEA-1062A by General Electric Co., Schenectady, N. Y. Trip-free air circuit breakers are described in bulletin GEA-1159-A. Round-pattern switchboard instruments are described in bulletin GEA-55B. Watthour Meters are described in catalog GEA-615. Type CL-1 Turn-Pull Control Switch is described in bulletin GEA-440C. Outdoor Switching Equipment, high-voltage horn-gap switch, Type RA-1, is described in bulletin GEA-735B. G-E Synchronous Motors for driving, metal rolling mills, are described in bulletin GEA-1195.

DEVELOPING ELECTRIC SERVICE FOR THE FARM, as exemplified by the organizations and methods of the New York Power and Light Corp., is the subject of the N.E.L.A. publication No. 033 published by the Rural Electric Service Committee of the National Electric Light Assn., 420 Lexington Ave., New York City. The efforts of the New York Power & Light Corp. have resulted in an actual average use of 720 kw-hr. per farm consumer in New York state whose labor income is stated to be 76 per cent less than that paid for hired help. The factors that have contributed to this result are discussed in detail.

THE PRODUCT WITH A BACKGROUND is the title of an attractively illustrated bulletin in colors issued by the Norton Co., Worcester, Mass. This illustrates Norton grinding wheels for all types of metals and other materials and describes several types of grinding machines, refractories, porous plates and floor materials.

HANDBOOK has just been issued by the Electrical Association of New York, Inc., 100 East 45th St., New York, containing twelve sections covering each of the following classifications: Illumination, Industrial Control, Industrial Heating, Material Handling, Motors, Refrigeration, Signals, Signs, Switchboards and Panelboards, Tools, Ventilation and Wiring. This Handbook gives facts on each of the foregoing subjects that are of interest to both the buyer and seller of such equipment in each respective field. It is free from any trade names. Data were compiled by representative technical men in each industry covered, yet the information is so compact and concise that non-technical men can understand its contents.

FUNCTIONS, applications and advantages of evaporators for distilling boiler-feed make-up water are discussed in a new bulletin, No. 361, just issued by the Griscom-Russell Co., 285 Madison Ave., New York City. One of the topics of particular interest is the recently-developed Reducing-Valve Evaporator System designed to permit economical application of evaporators to industrial plants requiring considerable steam for process work. This system, which was originated by The Griscom-Russell Co. and is fully explained for the first time, is intended to provide process steam and boiler feed make-up at one operation and to extend the economical use of evaporators to many plants requiring a high percentage of boiler-feed make-up.

The bulletin further discusses in detail the history of evaporators, benefits of distilled boiler-feed and different types of evaporator systems that have been found advantageous for various operating conditions. Illustrations include photographs of installations and G-R evaporator designs, together with diagrams showing how evaporators may be associated with other plant apparatus for efficient operation. A heat benefit analysis in tabular form, gives definite data on savings effected by an evaporator system in a typical plant.

Power Plant Construction News

Ark., Dardanelle—The Glenwood Ice Co., Glenwood, is planning the establishment of a one-story ice-manufacturing plant at Dardanelle, reported to cost close to $40,000, with equipment. Plant will be operated by new interest to be known as the Dardanelle Ice Co.

Calif., San Francisco—Bell Brothers, Inc., Mills Building, have approved plans for a two-story ice and refrigerating plant at Twelfth and Bernice Streets, to cost close to $40,000, with equipment. E. H. Denke, 1317 Hyde Street, is architect.

Colo., Meeker—The City Council is said to be planning the installation of pumping machinery and auxiliary equipment in connection with a municipal water supply system, for which estimates of cost will soon be made. Black & Veatch, Mutual Building, Kansas City, Mo., are consulting engineers.

Fla., Jacksonville—The Continental Can Co., 1 Pershing Square, New York, plans installation of electric power equipment in proposed new branch plant at Jacksonville, entire project to cost over $175,000.

Ga., Atlanta—The United States Cold Storage Co., care of A. Epstein, 2001 West Pershing Road, Chicago, Ill., architect and engineer, is said to be arranging an early call for bids for proposed multi-story cold storage and refrigerating plant at Atlanta, including mechanical equipment, entire project reported to cost more than $500,000.

Ill., Glen Ellyn—Board of Improvements, Village Hall, is completing plans for a new purification plant in connection with extensions in sewerage system, to cost over $600,000. The Wells Engineering Co., Court House, Geneva, Ill., is engineer.

Ill., Peoria—The Commercial Solvents Corporation, 230 Park Avenue, New York, plans installation of electric power equipment in proposed new acetic acid manufacturing plant at Peoria, entire project reported to cost close to $500,000.

Ill., Peoria—The Muirson Label & Carton Co., Decatur Street and Irving Avenue, Brooklyn, N. Y., plans installation of electric power equipment in proposed new plant at Peoria, entire project to cost about $100,000.

Iowa, Independence—The City Council has authorized the purchase of a 400 kw. Diesel engine unit and auxiliary equipment for municipal power service. Charles L. King is city clerk.

Iowa, Toledo—The Iowa Railway & Light Co., Second Avenue, Cedar Rapids, is said to have plans maturing for a steam-operated electric power plant, in the vicinity of Toledo, reported to cost close to $350,000, with transmission line.

Kan., El Dorado—The Skelly Oil Co., Tulsa, Okla., plans installation of electric power equipment in proposed addition to refining plant at El Dorado, and new refinery in the vicinity of Pampa, Texas, entire project to cost over $500,000.

Ky., Louisville—The Palmer Asbestos & Rubber Co., 2741 Clybourne Avenue, Chicago, Ill., plans installation of electric power equipment in proposed new mill at St. Matthews, near Louisville, entire project to cost about $200,000; a boiler plant is planned.

Me., Waterville—The Harris Baking Co., plans installation of steam power equipment in connection with rebuilding of portion of baking plant, recently destroyed by fire with loss estimated in excess of $100,000.

Mich., Pontiac—The General Motors Truck Co., Pontiac plans installation of electric power equipment in proposed new addition at local plant, entire project to cost more than $400,000.

Mont., Kalispell—The Mountain States Power Co., Tacoma, Wash., plans extensions and improvements in power plant and system at Kalispell and vicinity, including installation of new generating unit for increased capacity, entire project to cost over $200,000.

Neb., Omaha—Haskins Brothers Co., Omaha, has plans under way for a steam power plant to cost about $50,000, with equipment. The Federal Engineering Co., Central Office Building, Davenport, Iowa, is engineer.

Neb., Omaha—The State Board of Control, State House, has preliminary plans under way for a new power plant for the Lincoln School for Deaf, to cost about $40,000, with equipment. Lawrie & Stockam, Paxton Building, are engineers.

N. J., Mount Holly—The Mount Holly Textile Co., 78 Washington Street, is said to be planning installation of electric power equipment in connection with proposed rebuilding of textile mill, recently destroyed by fire with loss of close to $100,000.

N. M., Hobbs—The Phillips Petroleum Co., Bartlesville, Okla., plans installation of gas engine equipment, air compressors and other mechanical equipment in proposed new gasoline refining plant near Hobbs, entire project to cost in excess of $500,000.

N. Y., Brooklyn—Board of Trustees, Long Island College Hospital, Henry and Pacific Streets, has filed plans for a one-story boiler plant at institution to cost abuot $50,000, with equipment. William Higginson, 101 Park Avenue, New York, is architect.

N. Y., Tarrytown—The Fisher Body Corporation, General Motors Building, Detroit, Mich., plans installation of electric power equipment in proposed new plant unit at Tarrytown to cost over $500,000.

N. C., Roseboro—The Denny Veneer Co., plans installation of electric power equipment in connection with proposed rebuilding of portion of plant, recently destroyed by fire with loss reported at close to $100,000.

Ohio, Youngstown—Youngstown Sheet & Tube Co. will install electric power equipment in proposed new welded steel pipe manufacturing unit to be constructed at the Brier Hill works, entire project to cost about $2,000,000.

Okla., Chickasaw—The City Council is said to be planning the installation of pumping machinery and auxiliary equipment for municipal water service.

Ore., Hood River—The City Council has plans under way for a municipal power plant and system, for which estimates of cost will soon be made. Stevens & Koon, Spalding Building, Portland, are engineers.

Pa., Easton—The Board of Trustees, Lafayette College, has plans under way for a new steam power plant at institution, to cost over $80,000, with equipment. L. T. Clauder, Bankers Building, Philadelphia, is engineer.

Pa., Grove City—The Cooper-Bessemer Corporation plans installation of electric power equipment in connection with an expansion and improvement program at gas engine and air compressor manufacturing plant at Grove City, and Mount Vernon, Ohio, entire project to cost close to $250,000.

S. D., Hot Springs—The Central West Public Service Co., Omaha, Neb., has approved plans for extensions and improvements in power plant at Hot Springs, to cost close to $80,000, with equipment.

Texas, Freeport—The Freeport Texas Co., 52 Wall Street, New York, plans installation of steam power equipment in connection with extensions and improvements in local plant, entire project reported to cost over $150,000.

Texas, Port Arthur—The Texas Co., is said to be planning installation of electric power equipment in connection with proposed rebuilding of portion of local oil refining plant, recently destroyed by fire with loss reported in excess of $300,000.

Utah, Beaver—The American Smelting & Refining Co., Salt Lake City, is said to be planning installation of additional equipment at its Frisco Lulu mine, near Beaver, including air compressor, electric hoist and accessories.

Wis., Campbellsport—The Village Council plans installation of pumping machinery and auxiliary equipment in connection with a new municipal water system and sewerage works, to cost $115,000. The P. L. Clark Engineering Co., 208 West College Avenue, Appleton, Wis., is engineer.

Wis., New London—The Little Wolf Power Co., New London, is said to have plans maturing for proposed hydroelectric power plant on the Little Wolf River, reported to cost close to $100,000. L. A. DeGuere, Mead-Witter Building, Wisconsin Rapids, Wis., is engineer.

Va., Winchester—The H. J. Heinz Co., 1062 Progress Street, Northside, Pittsburgh, Pa., plans installation of electric power equipment in proposed new apple products plant at Winchester, entire project reported to cost more than $100,000; a boiler house is contemplated.